

Diagnostic X Multi-Axis Beamline

A. Paul

April 5, 2000

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

This report has been reproduced directly from the best available copy.

Available electronically at <http://www.doc.gov/bridge>

Available for a processing fee to U.S. Department of Energy
And its contractors in paper from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-mail: reports@adonis.osti.gov

Available for the sale to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-mail: orders@ntis.fedworld.gov
Online ordering: <http://www.ntis.gov/ordering.htm>

OR

Lawrence Livermore National Laboratory
Technical Information Department's Digital Library
<http://www.llnl.gov/tid/Library.html>

Diagnostic X Multi-Axis Beamline

by
Art Paul

April 5, 2000

EXPORT CONTROLLED INFORMATION

CONTAINS TECHNICAL INFORMATION WHOSE EXPORT IS RESTRICTED BY STATUTE. VIOLATIONS MAY RESULT IN ADMINISTRATIVE, CIVIL, OR CRIMINAL PENALTIES. LIMIT DISSEMINATION TO U.S. DEPARTMENT OF ENERGY EMPLOYEES AND CONTRACTORS AND OTHER U.S. GOVERNMENT AGENCIES. THE COGNIZANT PROGRAM MANAGER MUST APPROVE OTHER DISSEMINATION. THIS NOTICE SHALL NOT BE SEPARATED FROM THE ATTACHED DOCUMENT.

REVIEWER (SIGNATURE) _____

DATE: _____

6/2/00

Diagnostic X Multi-Axis Beamline¹

Arthur C. Paul

April 5, 2000

1. Introduction

Tomographic reconstruction of explosive events require time resolved multipal lines of sight. Considered here is a four (or eight) line of sight beam layout for a nominal 20 MeV 2000 Ampere 2 microsecond electron beam for generation of x-rays 0.9 to 5 meters from a given point, the "firing point". The requirement of a millimeter spatial x-ray source requires that the electron beam be delivered to the converter targets with sub-millimeter precision independent of small variations in beam energy and initial conditions. The 2 usec electron beam pulse allows for four bursts in each line, separated in time by about 500 microseconds. Each burst is divided by a electro-magnetic kicker into four (or eight) pulses, one for each beamline. The arrival time of the four (or eight) beam pulses at the x-ray target can be adjusted by the kicker timing and the sequence that the beams of each burst are switched into the different beamlines. There exists a simple conceptual path from a four beamline to a eight beamline upgrade.

The eight line beamline is built up from seven unique types of sub-systems or "blocks". The beamline consists of 22 of these functional blocks and contains a total of 455 individual magnets, figure 1. The 22 blocks are inter-connected by a total of 30 straight line inter-block sections (IBS). Beamlines 1-4 are built from 12 blocks with conceptual layout structure shown in figure 2. Beamlines 5-8 are built with an additional 10 blocks with conceptual layout structure shown in figure 3. This beamline can be thought of as looking like a lollipop consisting of a 42 meter long stick leading to a 60 by 70 meter rectangular candy blob consisting of the eight lines of sight. The accelerator providing the electron beam is at the end of the stick and the firing point is at the center of the blob.

The design allows for a two stage implementation. Beamlines 1-4 can be installed to provide a tomographic azimuthal resolution of 45 degrees. An upgrade can later be made by adding beamlines 5-8 azimuthally indexed so as to provide an azimuthal resolution of 22.5 degrees. All eight beamlines point down by 10 degrees (pitch). The x-ray converter target can be located along each beamline anywhere between 0 to 5 meters from the firing point. An example of inter-facing the Diagnostic X facility with the Darht II accelerator located at LANL will be given.

¹

¹ U4EA:/export/work/acpaul/diagn/dx12

CONTENTS

1	Introduction	1
	Contents	2
2	Scope	3
3	Modularity	3
4	Generating the layout	4
5	Hitting the Firing Point	4
6	Sizing up the Magnets	7
7	Magnet Naming Convention	8
8	Beam Transport	9
9	Interface Between Accelerator and Diagnostic X	10
10	Trip to the Dump	10
11	Trip Down the Beamline	10
12	Achromatic Bend Systems	10
13	The Seven Sub-Systems	12
14	KQS - The Beam Burster	13
15	B10 - The 10 Degree Achromatic Bend	14
16	B45 - The 45 Degree Achromatic Bend	16
17	B67 - The 67. 5 Degree Achromatic Bend	16
18	B90 - The 90 Degree Achromatic Bend	17
19	K90 - The 90 Degree Kicker Achromatic Bend	18
20	A90 - The 90 Degree Achromatic Break-out	20
21	Magnet Alignment Requirements	21
22	Timing	22
23	Kicker Firing Sequence	23
24	Beamline 1	24
25	Beamline 2	25
26	Beamline 3	26
27	Beamline 4	26
28	Beamline 5	27
29	Beamline 6	28
30	Beamline 7	29
31	Beamline 8	30
32	Yet Reborn Again	31
	TRANSPORT DATA	33
	LIST OF FIGURES	48
	FIGURES	54

2. Scope

This report will describe the choices we have made and why we made those choices in designing the diagnostic X beamline. We will give the details of the design for each block used to build the individual beamlines and the techniques used to connect these blocks so as to deliver the beam along the specified yaw and pitch angles. We will review the design and tuning of each of the beamlines as constructed from those blocks. As an example of the flexibility of this design we use throughout this work a 2.0 meter conjugate with actual (but not shown in this report) ability to accommodate a 0.9 to 5.0 meter value. Finally, we conclude with a list of things that we would re-consider if we were to redo the beamlines from scratch.

3. Modularity

The high degree of modularity incorporated into the design of the diagnostic X beamline allows its construction from a set of seven unique structures called "blocks". This modularity allows considerable simplification in the tuning of the beamline and engineering of the magnets. These seven block types are in turn made up from four types of quadrupole magnets, two types of solenoid magnets, and two types of bending magnets. All eight electro-magnetic kickers are of one design. That's right, a total of 455 magnets consisting of only nine individual magnet types itemized in table 1__.

Table 1__
Magnets

Magnet	Type	Lines 1-4	Lines 5-8	Total Number	Length(m)	Maximum Field(kG)	Diameter Aperture(cm)
1 Kicker	Pulsed	4	4	8	1.4	0.0085	16
2 Quad	Septum	1	0	1	0.51		38
3	Collins	3	0	3	0.20		10
4	Collins	6	8	14	0.20		16
5	Standard	154	142	278	0.20		16
6 Bend	Septum	3	4	7	0.5	1.0	16
7	Dipole	44	40	84	0.5	1.0	16
8 Solenoid	Final Focus	4	4	8	0.050	20	4
9	Transport	29	23	52	0.2	3	16
		238	217	455			

The seven types of blocks are designated A90, B10, B45, B67, B90, K90, and KQS. They are: 1) A90, 90 degree achromatic bend breaking out from the accelerator hall, 2) B10, 10 degree achromatic bend, 3) B45, approximately 45 degree achromatic bend, 4) B90, 90 degree achromatic bend, 5) KQS, kicker-quadrupole septum beam dump system, 6) K90, kicker plus dipole septum incorporated into a 90 degree achromatic bend, and 7) B67, 67.5 degree achromatic bend indexing lines 5 through 8 by 22.5 degrees with respect to lines 1 through 4. These blocks are itemized in table 2__.

Table 2
Blocks

	Block name	Number Lines 1-4	Number Lines 5-8	Total Lines 1-8	use
1	A90	1	0	1	accelerator break-out
2	KQS	1	0	1	kicker quadrupole septum beam dump
3	B10	3	2	5	10.0 deg achromatic bend
4	B45	2	2	4	45.0 deg achromatic bend
5	B67	0	1	1	67.5 deg achromatic bend
6	B90	1	2	3	90.0 deg achromatic bend
7	K90	4	3	7	90.0 deg kicker achromatic bend
		----	----	----	
		12	10	22	

4. Generating the Layout

The overall layout is sized by noting that the scaling laws to be discussed shortly and the achromatic bending blocks along with their matching sections give blocks that are of the order of ten meters in path length. For a block that bends by angle α , we have a geometric foot print of $10\cos\alpha, 10\sin\alpha$ meters. From the accelerator exit to the firing point we will transverse at least six blocks along any of the beamlines, the accelerator break-out block, the kicker-septum-dump block, a 10 degree leveler block, a kicker into given line, a yaw selection block, and a 10 degree pitch block leading to the firing point. This sets the expected size of diagnostic X to be on the order of 60 meters. When the requirements for all eight lines are scoped out we selected the firing point to be located at 70.0, 35.0, -5.90 (Global X, Y, Z) meters relative to the origin of the DX facility. Each of the eight lines was then adjusted to hit this location by adjusting selected drifts lengths between the various blocks as will be discussed in next section.

The vertical drop of 5.9 meters is the result of two requirements. The lines outside the accelerator hall be around twelve feet below grade to accommodate access roads at grade level, and that the firing point be addressed at a -10 degree pitch angle. Accommodation of a 5 meter conjugate between the final focus solenoid and the firing point requires around a ten meter section between the last block and the firing point. At a 10 degree pitch, this drops the line an additional 5.7 feet resulting in the elevation of the firing point being -5.9 meters below the accelerator line.

5. Hitting the Firing Point

Each of the beamlines is defined to begin at a certain point and to end at their respective X-ray converter target, table 3. The starting points of the various lines are as shown in figures 2 and 3. For line 1 the "start point" is the exit of the accelerator. The "start points" for all other lines are the entrance points of the S3 solenoids matching the kickers that switch the lines, i.e., the start of the K90 block for that beamline.

Table 3__

Line	Start Point	End Point
1	1	14
2	8	20
3	16	26
4	22	32
5	10	40
6	36	48
7	44	54
8	50	60

These lines consists of the various magnet blocks separated by inter-block (IB) drift regions. These drift regions have names like IB01, IB02, IB30. These inter-block separations are used to position the end of each line onto the firing point, tables 4__ and 5__. Regions that are shared between several lines effect all those lines and can not be adjusted to bring a single line onto the firing point. Note that each line has at least two inter-block drifts that are unique to that line. Also note that drifts IB01, IB02, IB03, and IB04 have values that have not been adjusted. IB01's odd value reflects the continuously changing location of the end of the accelerator.

Table 4__
IB distances for lines 1, 2, 3, and 4

IBX	length	start point	end point	Lines effected
IB01	0.5411	1	2	1, 2, 3, 4, 5, 6, 7, 8
IB02	1.0000	3	4	1, 2, 3, 4, 5, 6, 7, 8
IB03	0.5000	5	6	1, 2, 3, 4, 5, 6, 7, 8
IB04	9.2002	7	8	1, 2, 3, 4, 5, 6, 7, 8
IB05	13.4500	9	10	1, 5, 6, 7, 8
IB06	4.2893	11	12	1
IB07	5.7175	13	14	1
IB08	12.3689	15	16	2, 3, 4
IB09	6.4610	17	18	2
IB10	5.8160	19	20	2
IB11	2.7578	21	22	3, 4
IB12	3.4912	23	24	3
IB13	5.7160	25	26	3
IB14	4.5235	27	28	4
IB15	6.2510	29	30	4
IB16	5.5590	31	32	4

Table 5____
IB distances for lines 5, 6, 7, and 8

IBX	length	start point	end point	Lines effected
IB01	0.5411	1	2	1, 2, 3, 4, 5, 6, 7, 8
IB02	1.0000	3	4	1, 2, 3, 4, 5, 6, 7, 8
IB03	0.5000	5	6	1, 2, 3, 4, 5, 6, 7, 8
IB04	9.2002	7	8	1, 2, 3, 4, 5, 6, 7, 8
IB05	13.4500	9	10	1, 5, 6, 7, 8
IB17	14.3756	33	34	5, 6, 7, 8
IB18	5.0550	35	36	5, 6, 7, 8
IB19	4.7000	37	38	5
IB20	5.7160	39	40	5
IB21	23.800	41	42	6, 7, 8
IB22	5.4353	43	44	6, 7, 8
IB23	7.3192	45	46	6
IB24	5.5590	47	48	6
IB25	2.7722	49	50	7, 8
IB26	4.1656	51	52	7
IB27	5.7200	53	54	7
IB28	4.5289	55	56	8
IB29	6.9273	57	58	8
IB30	5.5600	59	60	8

For beamlines 2, 4, 6, and 8, the exact bend angle and roll of the B45 blocks must also be adjusted to hit the correct elevation and yaw angles, table 6____. Here we use the field of the nominal 45 degree bend (four 11.25 degree bend magnets) and their roll angle along with the inter-block drifts IB9 and IB10 for line2, IB14, IB15 and IB16 for line 4, IB23 and IB24 for line 6, IB28, IB29, and IB30 for line 8, to generate the required global survey X, Y, Z, yaw and pitch coordinates, table 7____.

Table 6____
"45" degree bend angle and roll

Line	Bend Degrees	Field kG	Roll Degrees
2	-45.8643	-0.273746	-14.00189
4	45.8650	0.273750	14.00200
6	45.8733	0.2738	14.0
8	-45.8611	-0.273727	-14.00238

Table 7____ show the x-ray converter coordinates 0.1 meters pass the final focus solenoid for each of the beam lines for a 2.0 meter conjugate. The beam at the final focus solenoid is axially symmetric so that the roll angle has no significance. Table 8____ show the firing point coordinates generated at the end of each of the lines. Note that all coordinates except yaw are identical ant the firing point.

Table 7
Location of the X-ray Converter Targets

Line	Global X meters	Global Y meters	Global Z meters	Yaw degrees	Pitch degrees	Roll degrees
1	68.03037	-5.55312	35.00656	90.00120	-9.99999	90.00020
2	68.60733	-5.55228	33.60752	45.00041	-10.01326	-9.85072
3	70.00065	-5.55283	33.03038	-0.00001	-10.00030	0.00015
4	71.39275	-5.55281	33.60771	-45.00100	-10.00040	9.85091
5	69.25027	-5.55288	36.81975	157.50190	-10.00000	89.99993
6	70.75371	-5.55282	36.82001	-157.50600	-10.00000	9.84783
7	71.81963	-5.55353	35.75404	-112.50700	-10.00020	-0.00025
8	71.87982	-5.55290	34.24634	-67.49980	-10.00000	-9.85202

Table 8
Location of the Firing Point

Line	Global X meters	Global Y meters	Global Z meters	Yaw degrees	Pitch degrees	Roll degrees
1	70.00000	-5.90041	35.00656	90.00120	-9.99999	90.00020
2	70.00002	-5.90997	35.00001	45.00032	-10.00000	-9.85072
3	70.00065	-5.90014	34.99999	-0.00001	-10.00030	0.00015
4	70.00000	-5.90011	35.00040	-45.00100	-10.00040	9.85091
5	70.00395	-5.90018	35.00003	157.50190	-10.00000	89.99993
6	70.00014	-5.90013	35.00025	-157.50600	-10.00000	9.84783
7	70.00000	-5.90083	35.00009	-112.50700	-10.00020	-0.00025
8	70.00011	-5.90020	35.00010	-67.49980	-10.00000	-9.85202

The accuracy of the yaw and pitch angles is determined by the ± 0.1 mm precision of the firing point location. If a drift of 5 meters terminate at the FP within that tolerance, then the nominal 10 degree pitch angle or nominal yaw angle must be specified to within ± 0.0011 degrees, approximately 4 arc seconds.

6. Sizing Up the Magnets

Take A as the full aperture (bore) of the beamline. We then use the following scaling laws, table 9__, to size the various magnets used in the Diagnostic X beamline.

Table 9__
The summary

Quadrupoles	-->	$L = 1.25 A$
Dipoles	-->	$L = 3A$
Solenoids	-->	$L = A$
Minimum inter-magnet spacing	-->	$L = A$

L is the magnetic length of the element in question. Some one else might chose some other value of the scaling between aperture and length. After nearly four decades of experience, these are the scalings that

I have chosen. The aperture of the beamline from the exit of the accelerator through the quadrupole septum of the beamline leading to the straight ahead target and the Diagnostic X beamline is a nominal 16 cm diameter. This sets the length of the quadrupoles, dipoles and inter-magnet spacing to

Table 10__
The summary

Quadrupoles	L = 0.200	meters
Dipoles	L = 0.500	meters
Solenoid	L = 0.200	meters
Spacing	L = 0.200	meters

The 16 cm aperture is set by consideration of the resistive wall instability². This large aperture relative to the beam size alleviates problems with vacuum pump spacing and beam steering considerations.

7. Magnet Naming Convention

The beamlines consist of "blocks" separated by inter-block "IB" drift regions. Each block has a "starting and ending point", figures 2__ and 3__ and consists of combinations of solenoid, quadrupole, and dipole magnets. All solenoid names begin with s, all quadrupole names begin with q, all kickers begin with k, and all bends begin with bm. Magnets such as S3 (a solenoid) that are part of a kicker block are post-pended by the starting point of that block, e.g.,

ss3a	S3P08	S3 belonging to the K90 block switching between lines 2, 3, 4, and 1, 5, 6, 7, and 8
ss3c	S3P16	S3 belonging to the K90 block switching into line 2
ss3d	S3P22	S3 belonging to the K90 block switching between lines 3 and 4
ss3a	S3P10	S3 belonging to the K90 block switching into line 1
ss3e	S3P36	S3 belonging to the K90 block switching into line 5
ss3g	S3P44	S3 belonging to the K90 block switching into line 6
ss3g	S3P50	S3 belonging to the K90 block switching between lines 7 and 8

Likewise, the seven kickers that belong to the blocks just referred to have names

KP08, KP16, KP22, KP10, KP36, KP44, and KP50

The kicker belonging to block KQS has name KQS, a unique name while its matching solenoid S3 has name S3P04 (alias ss3) as the KQS block begins at point 4 and S3 is not a unique name. Similarly for bend magnets, quadrupoles and other solenoids belonging to the various blocks.

The inter-block regions IB01, IB02,..... IB30 (figures 2 and 3) have solenoid magnets for smooth transport with spacing selected to minimize the beam flutter within that space. The inter-block solenoids are named

SMIN

where M is the number of the solenoid within that inter-block space, I designates inter-block, and N is the inter-block designator 01, 02, .. 30. For example, the three transport solenoids in inter-block IB05 are named

² "Transverse Resistive Wall Instability of a Relativistic Electron Beam" G.J.Caporaso, W.A.Barletta, V.K.Neil, Particle Accelerators, 1980, Vol.11,page 71-79.

S1I05
S2I05
S3I05

Note that all names are six or fewer characters in length³.

The achromatic bends have four fold symmetry. These magnets will not be given unique names as there are four of each type in a given system. The name will be post-pended with the blocks starting point pXX, p designates point. The bend name will start with bm followed by the tens position of the bend angle of the total bend of the system, and the quadrupole name will begin with qf)focusing, qd)efocusing. The bends for the B10 blocks will then have names bmlp06, bmlp12, bmlp24, bmlp38, and bmlp52. The bends for the B90 blocks will have names bm9p10, bm9p42, and bm9p56.

Total bend	Tens position	Dipole 4 each	Quad 4 each	Quad 4 each
10	1	bmlpXX	qf1pXX	qd1pXX
45	4	bm4pXX	qf4pXX	qd4pXX
67.5	6	bm6pXX	qf6pXX	pq6pXX
90	9	bm9pXX	qf9pXX	qd9pXX

8. Beam Transport

TRANSPORT is a computer code for calculating properties of charged particle system using the matrix method in a six-dimensional phase space. The code used in this work⁴ was developed at LLNL as part of the ETA-ARM program and extends the long history of evolution of the transport code^{5 6 7 8}. The transport code had to be modified to accommodate some of the requirements of the Diagnostic X facility, namely, enlarging arrays for the long beamlines involved in this work. Several new commands were added to allow the over-plotting of the geometry layouts so several beamlines could be seen in one figure, figure 1.

The data used in the several sub-systems of Diagnostic X, and the data for the entire beamlines are given in tables at the end of this report. This data can be used with the versions of TRANSPORT installed on the various LLNL Beam Research computers, such as canopus.llnl.gov. The essential data format is consistent with the original (1965) transport. Data types and formats specific the the LLNL version can be removed to run the data sets with other version of transport if desired⁹.

³ Other naming conventions can be considered, such as including a designator for "which beamline" the component is in. The problem with that procedure is that some beamlines share components with other beamlines, making the use of a beamline designator a problem. The naming convention adopted here is carried out through out this report.

⁴ "Interactive Ion-Optic Transport Code", Arthur C. Paul, 9/29/98, Under preparation for use by the LLNL Beam Research Program.

⁵ "TRANSPORT, A Computer Program for Designing Beam Transport System", C.H.Moore, S.K.Howry, H.S.Butler, 1964, Stanford University.

⁶ "TRANSPORT, An Ion Optic Program, LBL Version", LBL-2697, Arthur C. Paul, February 1975.

⁷ "User Guide for LBL Teletype and Vista Transport", LBL-951, A.C.Paul, May 1972.

⁸ "On-Line Calculation of Beam Transport Systems to First and Second Order" J.S.Colonias, Arthur C. Paul, UCRL-19414, April 1970.

⁹ "Computer Codes for Particle Accelerator Design and Analysis", Helen Stokes Deaven, Kwok Chi Chan, LA-UR-90-1766, Los Alamos National Laboratory, for example: TRANSPORT PC-BNL, TRANSPORT-FERMI, TRANSPORT-LBL, page 220-223.

9. Interface Between Accelerator and Diagnostic X

The diagnostic X break-out from the Darht II building is severely constrained by lack of available real estate. There are four magnetic elements added to the nominal Darht II beamline, three quadrupoles and the first 22.5 degree dipole of a 90 degree achromatic bend, A90. These elements are located between solenoids S0 and S3 of the Darht II beamline. The 90 degree achromatic bend is rolled by 10 degrees to lower the elevation of the diagnostic X beamline. This system is followed by a kicker - quadrupole septum system, KQS, to switch the beam from the normal dump termination into the diagnostic X transport line. The switched portions of the beam then enter a 10 degree achromatic bend, A10, to re-establish the beam in the horizontal plane, -3.700 meters (12 feet) below the Darht II axis.

10. Trip to the Dump

The achromatic bend system A90 deflects the entire 2 micro-second beam outside the shielding wall. There the beam enters a kicker-quadrupole septum system (KQS) such that the normal beam is deflected into a dipole septum bend magnet that leads to a 80 kJ beam dump capable of absorbing the entire 2 micro-second beam. When the kicker of the KQS is pulsed, the beam deflection of the kickers bias dipole is cancelled and the beam passes through the center of the quadrupole septum and on to a series of three more quadrupoles that re-establish the beam matched to the following B10 block. When the kicker of KQS is not pulsed the DC bias dipole field of 8.5 Gauss deflects the beam into the quadrupole septum with an offset from the center of the quadrupole. This offset provides a dipole component of the quadrupole field in addition to a defocusing in the kicked plane that magnifies the deflection of the beam leading to the dipole septum. The kicker, quadrupole septum and dipole septum provide a total bend of 45 degrees worth of deflection. The beam is then intercepted by the diagnostic X beam dump.

11. Trip Down the Beamline

The beam that is not deflected into the diagnostic X dump, is kicked by the kicker of block KQS into the first 10 degree achromatic bend block, B10 shared by all eight beamlines. This 10 degree bend brings the beam back into the horizontal plane with an elevation of approximately 12 feet (exactly 3.700 meters) below the accelerator centerline. The next block encountered is a K90 that kicks the beam into lines 1, 5, 6, 7, and 8 or, when un-kicked, passes the beam un-deflected into lines 2, 3, or 4. These K90 achromatic bend systems act as fast beam switches leading to the eight view axes of the diagnostic X facility.

12. Achromatic Bend Systems

Several achromatic bend systems have been considered for use in this work, figures 4__, 5__, and 6__. The system based on three dipoles, DDD, is made achromatic by adjusting the inter magnet spacing, figure 4__A. That spacing is positive for total deflections of less than 60 degrees. For small deflections the spacing is quite large and is negative for bends larger than 60 degrees. For this reason, we do not consider this type of system. The system based on a divided bend with a quadrupole lens at the symmetry point between the two bends, DQD, require a double transverse phase space waist at the center of the quadrupole lens to minimize the required aperture, figure 5__B. The beam ellipticity (flutter) generated by the matching quadrupoles required to generate this double waist make this system unappealing for the beam parameters considered in this work.

The achromatic bend system chosen for Diagnostic X is based on $\frac{1}{2}\pi$ phase advance in four identical quadrupole-dipole-quadrupole sections, 4QDQ¹⁰. Figure 6__ shows a 45 degree achromatic bend.

¹⁰ K.L.Brown, Stanford University.

We will also use a 90 and 10 degree variant. With the element lengths determined by the scaling laws, the field of each 22.5 degree bend of a 90 degree system would be 0.537 kGauss at 20 MeV. A 90 degree achromatic bend then has a global XZ foot print of 3.886 X 3.886 meters. The field of each 2.5 degree dipole of a 10 degree achromatic bend is 0.059687 kGauss with foot print of 0.85216 X 9.5401 meters.

This achromatic system is built of four identical QF-D-QD magnet cells. The quadrupole lens QF and QD are adjusted to make the total phase advance in the four identical sections of the achromatic bend 2π in both the horizontal and vertical planes. This symmetry then leads to cancellation of almost all second order geometric aberrations and the first order chromatic terms.

Consider the example of the 90 degree block B90. The linear transformation matrix through the matching quadrupoles Q1-Q4, the achromatic bend, and the exit matching section, quadrupoles q5-q8, is given in the following table.

Table 12__
Matrix

-0.89217	-0.32881	0.	0.	0.	1.0330E-06
0.59254	-0.90248	0.	0.	0.	2.0116E-06
0.	0.	-0.98866	0.070616	0.	0.
0.	0.	-0.12676	-1.0024	0.	0.
4.0978E-08	-6.9984E-08	0.	0.	1.	-0.36164
0.	0.	0.	0.	0.	1.

The vector space that this matrix operates on has units of

$\begin{bmatrix} x(\text{cm}) \\ x'(\text{mr}) \\ y(\text{cm}) \\ y'(\text{mr}) \\ ds(\text{cm}) \\ \delta p(\%) \end{bmatrix}$

The linear transformation matrix of the 10 degree bend following the KQS system is

Table 13__
The summary

-0.87479	0.36684	0.	0.	0.	-1.5834E-05
-0.56193	-0.90749	0.	0.	0.	-2.6350E-05
0.	0.	-0.87809	0.36838	0.	0.
0.	0.	-0.56520	-0.90172	0.	0.
-1.4175E-06	2.4121E-06	0.	0.	1.	3.8605E-03
0.	0.	0.	0.	0.	1.

Note that R_{16} , R_{26} , R_{36} , and R_{46} matrix elements are small as required by the definition of a doubly achromatic bend system.

The required quadrupole strength to make this system achromatic does not strongly depend on the angle of bend as the fringe focusing of the dipole magnets is weak in comparison to the focusing generated by the quadrupoles. Table 14__ gives the parameters for the 10, 45, 67.5, and 90 degree bend systems.

Table 14____
Quadrupoles strength

Block name	Bend Angle	Qf kG/m	Qd kG/m	B Kg	Edge Angle
B10	10	8.28944	-8.2406	0.05968	1.25
B45	45 ¹²	8.55949	-9.25698	0.27540	5.675
B67	67.5	8.5722	-9.2540	-0.402886	-8.4375
B90	90	8.5847	-9.2370	0.53718	11.25

The edge angles are equal to half the angle of bend, focusing the beam in the non-bend plane for these rectangular pole face magnets. The rectangular pole face makes each magnet identical to any other magnet independent of its bend angle¹³. All magnets have 16 cm aperture with the bends having a length of 0.5 meters and the quadrupoles having a length of 0.25 meters. The dipole longitudinal length of 0.5 meter and path length of approximately 0.5 meters results from the small value of the bend angle of the individual dipoles, bends of 2.5 to 22.5 degrees. The path length is given by

$$L_p = \rho \alpha \quad 12.1$$

whereas the longitudinal width is given by

$$L_w = 2\rho \sin(\frac{1}{2}\alpha) \quad 12.2$$

In the small angle limit, $L_p \approx L_w$. Note that a wedge shaped pole magnet with edge angles of zero provide bend plane focusing, but require a different winding and pole geometry for each bend angle, thus these are not considered in this report.

13. The Seven Sub-Systems

The DX facility is built from seven sub-systems, six of which are doubly achromatic bends of 10, 45, 67.5, 90, 90, and 90 degrees designated as B10, B45, B67, B90, A90, and K90. The one non-bend system, KQS, consists of a kicker and quadrupole septum to chop the beam from the accelerator into four bursts separated by about 500 nsec. The sections of beam selected for transport to the firing point travel straight ahead, while the sections of beam not selected for transport to the firing point are deflected 45 degrees into a beam dump.

Table 15____
Dipoles of the achromatic bend systems

Total system bend, degrees	Magnetic Length(m)	field (kG)	Bend per magnet(deg)	gradient	entrance angle(d)	exit angle(d)
10	0.500	0.059687	2.5	0	1.25	1.25
45	0.500	0.27540	11.25	0	5.675	5.675
67.5	0.500	0.402886	16.875	0	8.4375	8.4375
90	0.500	0.537182	22.5	0	11.25	11.25

The bends use rectangular poles rotated by half the per magnet bend so that the normal to the entrance and exit pole edges are rotated by that angle relative to the beam direction. This orientation provides

¹² *) The total system yaw and pitch angles are 45.000 and -10.000 degrees. The actual total bend angle is 46.141 degrees, each magnet bending by 11.5354 degrees.

¹³ "The optic of Dipole Magnets", J.J.Livingood, 1969.

non-bend plane fringe focusing at both the entrance and exit edges of the magnets.

14. KQS - The Beam Burster

The kicker - quadrupole septum system divides the 2 micro-second beam into four pieces. Each of these pieces is further sub-divided into the beam pulses that comprise a burst by the kickers of the K90 blocks leading to each of the eight beamlines. When the kicker of the KQS block kicks the beam, the beam passes through the center of the quadrupole septum and on to quadrupoles QXH, QXV, and QXW that re-establishes a match to the B10 block that immediately follows the KQS block. The beam that is not kicked is deflected into the beam dump. This system comprised of matching solenoid S3, kicker KQS, quadrupole septum Qsept, Collins quadrupoles QXH, QXV, QXW, forms the block KQS which fundamentally divides the 2 micro-second beam into the four sections that comprise the four bursts delivered onto the target.

The pulse format onto the target for a single beamline of the eight beamline configuration is four pulses of duration dT1, dT2, dT3, and dT4 each separated by about 500 nsec. Let dt be the rise and fall times of these pulses. Then the first burst generated by KQS must have temporal length

$$\Delta T_1 = 8(dT1+2dt)$$

for the eight beamlines. The second, third and fourth bursts separated by 500 nsec each would have lengths

$$\Delta T_2 = 8(dT2+2dt)$$

$$\Delta T_3 = 8(dT3+2dt)$$

$$\Delta T_4 = 8(dT4+2dt)$$

The beam that is not kicked by the kicker, is deflected one degree by the bias dipole of the kicker. After the 2.5 meter drift between the exit of the kicker and the start of the quadrupole septum, the beam enters the quadrupole septum offset by 5.58 cm. The quadrupole is de-focusing in the kicked plane. The beam being off center in the quadrupole sees both a dipole and quadrupole (gradient) component to the magnetic field. The dipole component magnifies the deflection generated by the kicker bias dipole to about 22 degrees on exit of the quadrupole. This beam then enters a dipole septum magnet which further increase the deflection of the beam to 45 degrees. This beam then enters the main 80 kJ beam dump. figure 7.

Table 16__
Quadrupole septum and symmeterizing lens

Name	Type	L(m)	B(kG)	Aperture(cm)
S3	19.	0.25	1.34	16
QXS	5.	0.51	-4.50	38
QXH	5.	0.25	6.0	6
QXV	5.	0.25	-5.0	6
QXW	5.	0.25	2.6	6

The transport data for the KQS block is given in table 47. The straight ahead length of this system is 6.96 meters. The beam exiting KQS is matched to the following B10 10 degree achromatic bend block so as to minimize beam flutter in that system. The linear transformation matrix for this system for the beam kicked into the straight ahead line is given in table 17. This matrix extends from the entrance of S3P04 to the exit of QXW.

Table 17
Matrix of straight ahead KQS

-0.11929	-0.14195	-0.029814	-0.035476	0.	0.
1.1161	-6.5618	0.27892	-1.6399	0.	0.
0.040944	0.24735	-0.16383	-0.98974	0.	0.
-0.46146	-1.3520	1.8465	5.4099	0.	0.
0.	0.	0.	0.	1.	0.0043167
0.	0.	0.	0.	0.	1.

The beam entering the KQS system has sigma matrix

$$\begin{cases} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{cases} = \begin{cases} 2.985 \text{ cm} \\ 1.005 \text{ mr} \quad 0.018 \\ 2.993 \text{ cm} \quad 0.000 \quad 0.000 \\ 1.005 \text{ mr} \quad 0.000 \quad 0.000 \quad 0.016 \end{cases} \quad 14.I$$

The beam exiting the KQS system has parameters matched to the input conditions of the following B10 block that minimized the beam flutter in that block, figure 22, and 32.

$$\begin{cases} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{cases} = \begin{cases} 0.398 \text{ cm} \\ 7.560 \text{ mr} \quad -0.075 \\ 1.148 \text{ cm} \quad 0.000 \quad -0.001 \\ 8.057 \text{ mr} \quad 0.000 \quad 0.001 \quad -0.946 \end{cases} \quad 14.I$$

After inter-block IB3, this beam becomes

$$\begin{cases} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{cases} = \begin{cases} 0.528 \text{ cm} \\ 7.560 \text{ mr} \quad 0.659 \\ 0.778 \text{ cm} \quad -0.001 \quad -0.001 \\ 8.057 \text{ mr} \quad 0.001 \quad 0.001 \quad -0.878 \end{cases} \quad 14.I$$

The matched input beam that minimizes the flutter in block B10p06.

15. B10 - The 10 Degree Achromatic Bend

The traditional three dipole achromatic bend with wedge shaped magnets bending left, bend right, bend left symmetry requires a given magnet separation to make $R_{16} = R_{26} = 0$. That separation, L , is given by

$$\frac{L}{\rho} = \frac{2\cos(\alpha) - 1}{\sin(\alpha)}$$

where ρ is the radius of curvature, and α is the bend angle. We have solutions with positive L for any angle $\alpha < 60$ degrees. For a 10 degree bend system

$$\frac{L}{\rho} = 5.5838$$

This leads to a rather long physical separation between magnets. For this reason we adopt the achromatic four fold symmetry system even for the 10 degree bend where each dipole only bends the beam by 2.5 degrees.

The total path length through the 10 degree system along the reference trajectory is 9.6000 meters including the four matching quadrupoles on entrance and exit of the system, figure 11. The global coordinate XY rectangular foot print is 0.852161 by 9.540082 meters. This system requires a quadrupole quadruplette at its entrance and exit to provide proper phase space matching. These matching quadrupoles have parameters approximately given in table 18__.

Table 18__
10 degree achromatic bend matching quadrupoles

	Length meters	Gradient kG/meter	aperture cm
Q1	0.200	-3.000	16
Q2	0.200	4.000	16
Q3	0.200	3.300	16
Q4	0.200	-5.500	16
QF4		-6.000	
Q5	0.200	-1.2564	16
Q6	0.200	6.6427	16
Q7	0.200	-3.6742	16
Q8	0.200	-1.1006	16

These quadrupole settings match a 3.0 cm diameter beam into the the 10 degree achromatic bend system. In order to match the beam out of the system to a round beam of 2.0 cm diameter, we modify the last quadrupole of the fourth bend cell QF4 (table 18__ above) to -6.0000 kG/M. The transport data for the B10 achromatic bend block is shown in table 41. The 1 cm radius beam exiting the B10 blocks ending beamlines 1, 3, 5 and 7 provide the correct radius for the final focus solenoid focusing the beam onto the X-ray converter targets.

Table 19__
Matrix of 10 degree bend B10

-0.62217	-0.031949	0.	0.	0.	1.6797E-04
0.64268	-1.5743	0.	0.	0.	9.6115E-06
0.	0.	-0.56697	0.36853	0.	0.
0.	0.	-1.0389	-1.0884	0.	0.
1.0202E-05	-2.6475E-05	0.	0.	1.	0.0018621
0.	0.	0.	0.	0.	1.

$$\begin{pmatrix} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} & r_{21} \\ \sqrt{\sigma_{33}} & r_{31} & r_{32} \\ \sqrt{\sigma_{44}} & r_{41} & r_{34} & r_{43} \end{pmatrix} = \begin{pmatrix} 0.984 \text{ cm} \\ 3.048 \text{ mr} & 0.002 \\ 0.992 \text{ cm} & 0.000 & 0.000 \\ 3.015 \text{ mr} & 0.000 & 0.000 & 0.001 \end{pmatrix} \quad 15.1$$

16. B45 - The 45 Degree Achromatic Bend

The 45 degree achromatic bend matches a beam of 1.5 cm radius. This match requires a quadrupole quadruplette at its entrance and exit. The total system length (along the reference trajectory) is 10.4000 meters, figure 13. The global XY rectangular foot print is 3.68907 by 9.16118 meters. The actual total bend angle is 46.1414 degrees. Remember that these 45 degree bends are "rolled" to generate both a 45.000 degree yaw and a 10 degree pitch leading to the target of beamlines 2, 4, 6, and 8. The transport data for the B45 achromatic bend block is shown in table 42.

Table 20____
The summary

	Length meters	Gradient kG/meter	aperture cm
Q1	0.200	-3.000	16
Q2	0.200	4.000	16
Q3	0.200	3.300	16
Q4	0.200	-5.500	16
Q5	0.200	7.0702	16
Q6	0.200	-6.0112	16
Q7	0.200	-2.7502	16
Q8	0.200	2.7753	16

Table 21____
Matrix of 45 degree bend, B45

-0.95750	-0.041361	0.	0.	0.	6.9412E-05
0.40943	-1.0267	0.	0.	0.	7.9539E-05
0.	0.	-0.25050	-0.68316	0.	0.
0.	0.	1.2800	-0.50121	0.	0.
0.00001047	-0.0000068	0.	0.	1.	-0.089597
0.	0.	0.	0.	0.	1.

$$\begin{Bmatrix} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \ r_{21} \\ \sqrt{\sigma_{33}} \ r_{31} \ r_{32} \\ \sqrt{\sigma_{44}} \ r_{41} \ r_{34} \ r_{43} \end{Bmatrix} = \begin{Bmatrix} 1.510 \text{ cm} \\ 1.987 \text{ mr} \ -0.001 \\ 1.514 \text{ cm} \ 0.000 \ 0.000 \\ 1.982 \text{ mr} \ 0.000 \ 0.000 \ -0.001 \end{Bmatrix} \quad 16.I$$

17. B67 - The 67.5 Degree Achromatic Bend

The 67.5 degree achromatic bend matches a beam of 1.5 cm radius. The total system length (along the reference trajectory) is 10.4000 meters. The global XY rectangular foot print is 4.93040 by 7.87875 meters. The setting of the matching quadrupoles for this block are given in table 22____. The transport data for the B67 achromatic bend block is shown in table 43.

Table 22__
The summary

	Length meters	Gradient kG/meter	aperture cm
Q1	0.200	-3.000	16
Q2	0.200	4.000	16
Q3	0.200	3.300	16
Q4	0.200	-5.500	16
Q5	0.200	7.1342	16
Q6	0.200	-6.4502	16
Q7	0.200	-2.1611	16
Q8	0.200	2.5845	16

Table 23__
Matrix of 67.5 degree bend, B67

-0.95729	-0.038254	0.	0.	0.	6.9561E-06
0.40415	-1.0285	0.	0.	0.	8.2256E-06
0.	0.	-0.19769	-0.70472	0.	0.
0.	0.	1.2923	-0.45156	0.	0.
1.0245E-06	-6.6803E-07	0.	0.	1.	-0.19996
0.	0.	0.	0.	0.	1.

$$\begin{Bmatrix} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{Bmatrix} = \begin{Bmatrix} 1.508 \text{ cm} \\ 1.990 \text{ mr } 0.000 \\ 1.518 \text{ cm } 0.000 \text{ } 0.000 \\ 1.977 \text{ mr } 0.000 \text{ } 0.000 \text{ } 0.000 \end{Bmatrix} \quad 17.I$$

18. B90 - The 90 Degree Achromatic Bend

The 45 degree achromatic bend matches a beam of 1.5 cm radius. The total system length (along the reference trajectory) is 10.050 meters, figure 17. The global XY rectangular foot print is 5.73694 by 5.8868 meters. The setting of the matching quadrupoles for this block are given in table 24__. The transport data for the B90 achromatic bend block is shown in table 44.

Table 24
The summary

	Length meters	Gradient kG/meter	aperture cm
Q1	0.200	-4.000	16
Q2	0.200	4.500	16
Q3	0.200	4.300	16
Q4	0.200	-6.500	16
QF4X	0.200	-4.000	16
Q5	0.200	5.8798	16
Q6	0.200	-4.7422	16
Q7	0.200	1.4441	16
Q8	0.200	0.2519	16

Table 25
Matrix of the 90 degree bend, B90

-0.89217	-0.15038	0.	0.	0.	6.3017E-07
0.59254	-1.0210	0.	0.	0.	1.5162E-06
0.	0.	-0.98866	0.2835	0.	0.
0.	0.	-0.12676	-0.97707	0.	0.
-2.2352E-08	-8.9071E-08	0.	0.	1.	-0.36288
0.	0.	0.	0.	0.	1.

$$\begin{Bmatrix} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{Bmatrix} = \begin{Bmatrix} 1.491 \text{ cm} \\ 2.012 \text{ mr} \quad -0.001 \\ 1.490 \text{ cm} \quad 0.000 \quad 0.000 \\ 2.014 \text{ mr} \quad 0.000 \quad 0.000 \quad 0.000 \end{Bmatrix} \quad 18.1$$

19. K90 - The 90 Degree Kicker Achromatic Bend

In order to incorporate the kicker dipole septum into the four cell $\pi/2$ phase advance achromatic system, we modify the magnet symmetry to that of a bend-quad-quad configuration. The first bend being the combined kicker, drift, septum. The beam is 3 cm in radius on entering the kicker matching solenoid S3. The exit quadrupole matching section establishes the beam to a 1.5 cm radius, round matched beam for further solenoid transport, figure 19__.

The total system length (along the reference trajectory) from the entrance of S3 to the exit of the last matching quadrupole, is 11.3500 meters for the kicked beam deflected 90 degrees, figure 19. The global XY rectangular foot print is 5.34710 by 7.63578 meters. The setting of the matching quadrupoles for this block are given in table 26__. The kick provided by the 1.400 meter long electro-magnetic kicker is equivalent to a dipole bending field of 8.527 Gauss. This deflects the beam by 1.000 degree.

After a 2.500 meter drift the deflected beam is offset by 5.58 cm from the un-kicked beam. It is here that the two beams, the kicked and un-kicked, enter the dipole septum magnet. The kicked beam sees a 513 Gauss field along the 0.5 meter length of the dipole while the un-kicked beam passes through a 0.5 meter region where the field is 0 Gauss. The size of the beam at the entrance and exit of the dipole septum is

	Entrance S3	Entrance Septum	Exit Septum	Path length(m)	Exit Block	
kicked	3.00	0.522	0.461	11.350	1.510	cm
un-kicked	3.00	0.523	0.463	6.430	1.202	cm

The exact size of the beam at the dipole septum is determined by the setting of the matching solenoid, S3. This setting must be a compromise between minimizing the beam size at the septum of the dipole septum and minimizing the beam flutter in the achromatic system of which the kicker-dipole septum is the first component. The transport data for the K90 achromatic bend block is shown in table 45.

Table 26
The summary

	Length meters	Gradient kG/meter	aperture cm
S3	0.200	2.000	16
QF4	0.200	-6.7596	16
QD4	0.200	7.6651	16
Q5	0.200	-1.5613	16
Q6	0.200	2.7088	16
Q7	0.200	-5.7093	16
Q8	0.200	4.2355	16

Note, that this system uses two different designs of the achromatic bend quadrupoles. The first QF4, QD4 are of the Collins design minimizing interference between the bend and straight ahead beamlines. This is followed by two pairs of standard quadrupoles for cells 2 and 3. The last cell of the achromat does not use explicit quadrupoles, figure 19. The matrix of the bend (kicked) path of block K90 extending from the entrance of S3 to the exit of Q8 is given in table 27.

Table 27
Matrix of the kicker switch

-2.9595	1.4217	-0.89096	0.42800	0.	-4.5697E-05
-1.4616	0.39228	-0.44000	0.11810	0.	-1.7651E-05
0.11955	-0.11999	-0.39711	0.39857	0.	0.
1.2446	-0.55405	-4.1342	1.8404	0.	0.
-2.3842E-07	1.1579E-06	-1.6391E-07	3.2447E-07	1.0	-0.39692
0.	0.	0.	0.	0.	1.0

The beam exiting the K90 90 degree bend path is given by sigma matrix

$$\begin{cases} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{cases} = \begin{cases} 1.510 \text{ cm} \\ 1.986 \text{ mr } 0.002 \\ 1.505 \text{ cm } 0.000 \text{ } 0.000 \\ 1.993 \text{ mr } 0.000 \text{ } 0.000 \text{ } -0.003 \end{cases} \quad 19.1$$

The straight ahead beam is generated when the kicker is not pulsed, i.e., the kicker is off. The beam passes through the matching solenoid S3, through the zero field kicker section, and a small drift region to the exit solenoid, S4. The total system length along this reference trajectory is 6.05 meters. The beam exiting the straight ahead line with solenoid S4 set to zero field is

$$\begin{cases} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \quad r_{21} \\ \sqrt{\sigma_{33}} \quad r_{31} \quad r_{32} \\ \sqrt{\sigma_{44}} \quad r_{41} \quad r_{34} \quad r_{43} \end{cases} = \begin{cases} 1.202 \text{ cm} \\ 6.563 \text{ mr } 0.925 \\ 1.202 \text{ cm } 0.000 \text{ } 0.000 \\ 6.563 \text{ mr } 0.000 \text{ } 0.000 \text{ } 0.925 \end{cases} \quad 19.2$$

The line transformation matrix of the K90 block in the un-kicked attitude extending from the entrance of S3 to the exit of solenoid S4 is given in table 28.

Table 28
Matrix of kicker switch (off) straight ahead line

-1.5974	0.59011	-0.48090	0.17765	0.	0.
-4.0358	0.91690	-1.2150	0.27603	0.	0.
0.48090	-0.17765	-1.5974	0.59011	0.	0.
1.2150	-0.27603	-4.0358	0.91690	0.	0.
0.	0.	0.	0.	1.0	0.0039879
0.	0.	0.	0.	0.	1.0

20. A90 - The 90 Degree Achromatic Break-out

The total system length (along the reference trajectory) from the entrance of quadrupole Q1 to the exit of the last matching quadrupole, Q8, is 10.8500 meters. figure 22 IO points 2 to 3 on the top of the beam envelop plot. The global XY rectangular foot print is 15.65542 by 4.68660 meters. This system is rolled by 10 degrees to bend the beam downward. The final exit global Z coordinate is -2.76047 meters, with a yaw and pitch of 90.001 and -9.9999 degrees. The setting of the matching quadrupoles for this block are given in table 29.

Table 29
The summary

	Length meters	Gradient kG/meter	aperture cm
Q1	0.200	10.000	16
Q2	0.200	-10.000	16
QF	0.200	8.1777	16
QD	0.200	-7.7165	16
QFX	0.200	-1.200	16
Q5	0.200	-1.0598	16
Q6	0.200	0.4111	16
Q7	0.200	3.1038	16
Q8	0.200	-2.3582	16

The transport data for the A90 achromatic bend block is shown in table 46. The linear transformation matrix from the entrance of Q1 to the exit of Q8 is given in table 30.

Table 30
Matrix of the break out achromat A90

-5.6310	0.18059	0.	0.	0.	-0.0014767
0.53426	-0.19472	0.	0.	0.	-0.00030332
0.	0.	2.3674	0.33629	0.	0.
0.	0.	-1.8022	0.16640	0.	0.
-2.4983E-04	3.4235E-05	0.	0.	1.	-0.34851
0.	0.	0.	0.	0.	1.

The beam on exit of block A90 must match solenoid S3 beginning the KQS block that immediately follows the short inter-block drift IB3 of 0.5 meters. This match requires a radius of 3.0 cm.

$$\begin{Bmatrix} \sqrt{\sigma_{11}} \\ \sqrt{\sigma_{22}} \, r_{21} \\ \sqrt{\sigma_{33}} \, r_{31} \, r_{32} \\ \sqrt{\sigma_{44}} \, r_{41} \, r_{34} \, r_{43} \end{Bmatrix} = \begin{Bmatrix} 2.985 \text{ cm} \\ 1.005 \text{ mr} \, -0.016 \\ 2.983 \text{ cm} \, 0.000 \, 0.000 \\ 1.002 \text{ mr} \, 0.000 \, 0.000 \, -0.017 \end{Bmatrix} \quad 20.1$$

21. Magnet Alignment Requirements

The magnet alignment accuracies have not been investigated. It has been assumed that there are sufficient steering coils along the beamlines the correct for any residual magnetic fields, the earths magnetic field, and any magnet mis-alignments.

22. Timing

There is considerable flexibility in the timing of the pulses on the X ray converter target. Consider each of the four bursts from the diagnostic X kicker KQS system to be divided into eight equal pulses. Each of these equal pulses can be kicked into any of the eight beamlines of the diagnostic X switching system. That is, the first pulse of burst 1 can be switched into beamline 1, or beamline 2, or beamline 3, etc. The second pulse of the first burst can be switched into any of the remaining beamlines. As to which pulse of any given burst are switch into which beamlines is done to minimized the temporal spread in the arrival times of the beams on the X-ray converter targets. Figures 24 and 25 show the temporal arrival times of beamlines 1-4 and 5-8 switched in numerical sequence.

The number of possible switching sequences are $4!=24$ for four lines and $8!=40310$ for eight lines. Tables 31__ and 32__ show the time interval and sequence order for the 24 possible sequences of the four lines 1-4, and the four lines 5-8. The time interval starts with the arrival of the head of the first pulse and ends with the tail of the fourth pulse of each of the four bursts separated by approximately 500 nsec. With firing sequence 3 4 2 1 all electrons arrive within a 69 nsec window for lines 1-4. With the firing sequence 8 7 6 5 all electrons arrive within a 175 nsec window for lines 5-8, figures 26__ and 27__.

Table 31__
Lines 1-4 timing vs line firing sequence

Duration - nsec.				Firing sequence			
burst1	burst2	burst3	burst4				
160.20	160.20	224.20	576.20	1	2	3	4
134.20	134.20	183.40	535.40	1	2	4	3
160.20	160.20	224.20	576.20	1	3	2	4
119.40	119.40	183.40	535.40	1	3	4	2
134.20	134.20	182.20	516.79	1	4	2	3
108.20	108.20	164.79	516.79	1	4	3	2
173.41	173.41	237.41	589.41	2	1	3	4
147.41	147.41	196.61	548.61	2	1	4	3
154.79	154.79	218.79	570.79	2	3	1	4
108.20	108.20	141.40	405.40	2	3	4	3
128.79	128.79	176.79	511.39	2	4	1	3
74.79	74.79	122.79	470.59	2	4	3	1
173.41	173.41	237.41	589.41	3	1	2	4
132.61	132.61	196.61	548.61	3	1	4	2
154.79	154.79	218.79	570.79	3	2	1	4
106.61	106.61	154.61	489.21	3	2	4	1
102.79	102.79	159.39	511.39	3	4	1	2
69.39	69.39	118.59	470.59	3	4	2	1
147.41	147.41	195.41	543.21	4	1	2	3
127.21	127.21	191.21	543.21	4	1	3	2
128.79	128.79	176.79	524.60	4	2	1	3
101.21	101.21	149.21	483.80	4	2	3	1
108.60	108.60	172.60	524.60	4	3	1	2
82.60	82.60	131.80	483.80	4	3	2	1

The selected switching order is identically repeated for each of the four bursts. In the preceding table the minimum time interval for lines 1-4 is generated with the firing sequence 3 4 2 1, figure 28__. In the following table the minimum time interval for lines 5-8 is generated with the firing sequence 8 7 6 5, figure 29__.

Table 32__
Lines 5-9 timing vs line firing sequence

Duration - nsec				Firing sequence			
burst1	burst2	burst3	burst4				
330.81	330.81	394.81	746.81	5	6	7	8
304.81	304.81	353.68	705.68	5	6	8	7
330.81	330.81	394.81	746.81	5	7	6	8
289.68	289.68	353.68	705.68	5	7	8	6
304.81	304.81	352.81	687.40	5	8	6	7
278.81	278.81	335.40	687.40	5	8	7	6
304.81	304.81	352.81	616.81	6	5	7	8
278.81	278.81	311.68	575.68	6	5	8	7
304.81	304.81	352.81	616.81	6	7	5	8
278.81	278.81	311.68	575.68	6	7	8	7
278.81	278.81	310.81	557.40	6	8	5	7
245.40	245.40	293.40	557.40	6	8	7	5
278.81	278.81	310.81	589.41	7	5	6	8
237.68	237.68	269.68	548.28	7	5	8	6
278.81	278.81	310.81	571.13	7	6	5	8
237.68	237.68	269.68	488.87	7	6	8	5
226.81	226.81	251.40	511.72	7	8	5	6
219.40	219.40	251.40	470.59	7	8	6	5
226.81	226.81	226.81	459.41	8	5	6	7
200.81	200.81	185.68	418.28	8	5	7	6
226.81	226.81	226.81	441.13	8	6	5	7
185.68	185.68	185.68	358.87	8	6	7	5
200.81	200.81	184.81	381.72	8	7	5	6
174.81	174.81	167.40	340.59	8	7	6	5

23. Kicker Firing Sequence

The number of beam traversals across the septum of the dipole septums of a K90 block is determined by the number of switchings that block performs. Each time the beam is switched it makes two crossings passed the septum. Most K90 blocks switch a beam pulse into its designated line once for each of the four bursts. This sweeps the beam across the septum eight times, four times starting and four times ending.

Block K90P08 switches between lines 2, 3, 4, and lines 1, 5, 6, 7, and 8. Depending on the exact sequence desired, the septum can be swept between $2 \times 4 = 8$ and $8 \times 4 = 32$ times. All other K90PXX blocks sweep the beam across the septum eight times. Figure 30__ show three timing scenarios for beamline firing sequence of 34218756, 12345678, and 54637281. These three sequence represent the 1) minimum pulse duration, 2) sequential line switching, and 3) maximum number of septum traversals. Here the relative time intervals of the pulses. T1, T2, T8 of the eight beamlines are switched into beamlines L1....L8 when kicker K90PXX goes positive above the baseline of figure 30__. Note kickers K90P16 and above (K90P22...K90P50) switch once per burst, i.e., sweep twice across the septum per burst. Kicker KQS switches once per burst, while kicker K90P08 switch between one and four times depending on the desired sequence.

24. Beamline 1

Beamline 1 extends from the exit of the accelerator to the firing point with all other beamlines branching from it, figure 31. Beamlines 2, 3, and 4 branch off at the location of the first K90 block when that block is off. When this block is fired, the beam is kicked into the remaining sections of beamline 1 which lead to either a B90 (B90P10) block in the four beamline option, or a K90 (K90P10) block in the eight beamline option and subsequently onto lines 5 through 8.

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 48. The data is a sequence of the data for blocks A90, KQS, B10, K90, K90, and B10 with the necessary inter-block drifts. The inter-blocks drifts of sufficient length are divided into shorter segments with transport solenoids to focus the beam. The match sections are adjusted to the nominal 3 cm diameter beam. The beam envelope is shown in figures 32 and 33. Figure 32 show the horizontal and vertical beams over plotted on the upper frame. The lens have been adjusted to minimize the beam profile changes. The lower three frames are the horizontal and vertical phase space and the beam spot size at the X-ray converter target. Figure 33 is the same plot with the horizontal and vertical traces above and below the axis. In addition, the ratio of the maximum value of X/Y or Y/X is plotted. This is the flutter which we try to minimize. Flutters of a few, one to eight are not a problem for beams that are small in comparison with the pipe diameter.

Table 33
data.L1

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP1	0.512300	0.512300	-0.008690	-0.008690	3.327000
IOP2	0.606200	0.606200	0.534710	0.534710	3.888100
IOP3	2.985000	2.993500	-0.015670	-0.017100	14.738100
IOP4	2.985100	2.993400	0.018010	0.016390	15.738100
IOP5	0.398000	1.147800	-0.075240	-0.945910	22.698100
IOP6	0.527800	0.777800	0.659370	-0.877950	23.198100
IOP7	0.764500	0.759500	0.001040	0.002870	33.248100
IOP8	3.012800	2.993300	0.949340	0.948140	42.448300
IOP9	1.510700	1.514300	-0.000690	-0.001560	53.798300
IOP10	3.067700	3.062800	0.870340	0.869210	67.248300
IOP11	1.485100	1.492500	-0.001260	-0.002820	78.598300
IOP12	1.135400	1.137200	-0.581160	-0.588150	82.887600
IOP13	1.004000	1.016000	-0.001980	-0.000740	92.937600
IOPTAR	0.032900	0.032800	0.035350	0.033850	98.655100

Three locations along beamline 1 have a six cm diameters at the match point into the K90 blocks designated IOP4, IOP8, and IOP10, table 33. The beam diameter at the exit of the "off" K90 blocks is three cm, points IOP9 and IOP11. The final transport to the X-ray converter target is adjusted to produce a tight spot, sub-millimeter at IOPTAR. The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 1 to the X-ray converter target is

Table 33B
Matrix of beamline 1

-4.2255E-03	2.3131E-03	5.8281E-02	-2.9050E-04	0.	-8.4499E-05
-7.3134E+01	-6.9999E-01	1.5581E+01	1.4127E+01	0.	-8.4943E-01
-5.7149E-02	9.4997E-04	-1.0119E-02	-2.1489E-03	0.	-2.5552E-05
-3.6259E+01	-1.3883E+01	6.7011E+01	-2.7797E+00	0.	-4.6825E-01
-2.3310E-03	2.8218E-04	4.1803E-03	-2.3727E-04	1.0000E+00	-1.1044E+00
0.	0.	0.	0.	0.	1.0000E+00

25. Beamline 2

Beamline 2 begins at point 8, figure 34___. The beam passes un-deflected by KP08 and is kicked by block KP16 into block B45 which bends by about 45 degrees but is rolled counter-clockwise to generate both the desired yaw and pitch angles addressing the X-ray converter target. Inter block spacings IB9 and IB10 are used to hit the firing point.

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 49___. The beam envelope is shown in figures 35__ and 36__.

Table 34__
data.L2

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP3	2.985000	2.993500	-0.015670	-0.017100	14.738100
IOP5	0.398000	1.147800	-0.075240	-0.945910	22.698100
IOP7	0.759500	0.764600	0.002870	0.001040	33.248100
IOP8	3.012800	2.993300	0.949340	0.948140	42.448300
IOP15	0.591800	0.594600	0.308210	0.306920	48.498300
IOP16	3.082500	3.076500	0.332650	0.333070	60.861200
IOP17	1.346200	1.346000	-0.257310	-0.257110	72.211200
IOP18	1.539600	1.537600	-0.029550	-0.026830	78.863400
IOP19	1.499400	1.499800	-0.000210	-0.000650	89.263400
IOPTAR	0.025400	0.025200	-0.029550	-0.025610	94.805600

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 2 to the X-ray converter target is

Table 34B
Matrix of beamline 2

-1.5382E-02	1.5555E-03	-4.1616E-02	-1.1725E-03	0.	-3.0767E-05
-8.1162E+01	-6.5233E+00	6.6380E+01	-1.6714E+01	0.	-2.8359E-01
-3.5257E-02	2.1792E-03	2.0063E-02	1.0776E-03	0.	9.8855E-06
-1.1443E+02	-1.4863E+01	-5.9646E+01	8.0905E+00	0.	2.3648E-01
5.3526E-04	-1.9130E-06	-1.9196E-03	1.9087E-07	1.0000E+00	-7.9841E-01
0.	0.	0.	0.	0.	1.0000E+00

26. Beamline 3

Beamline 3 begins at point 16, figure 37__. The beam passes un-deflected by KP08 and KP16 and is kicked by block KP22 into block B10P22 which bends 10 degrees down generating the desired pitch angle. Inter-blocks IB11, IB12 and IB13 are used to hit the firing point. Once IB11 is determined, it can not be further adjusted as it also effects beamline 4.

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 50__. The beam envelope is shown in figures 38__ and 39__.

Table 35__
data.L3

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP2	0.606200	0.606200	0.534710	0.534710	3.888100
IOP3	2.985000	2.993500	-0.015670	-0.017100	14.738100
IOP4	2.985100	2.993400	0.018000	0.016390	15.738100
IOP5	0.398000	1.147800	-0.075240	-0.945910	22.698100
IOP7	0.759500	0.764600	0.002870	0.001040	33.248100
IOP8	3.012800	2.993300	0.949340	0.948140	42.448300
IOP15	0.591800	0.594600	0.308210	0.306920	48.498300
IOP16	3.082500	3.076500	0.332650	0.333070	60.861200
IOP21	0.945300	0.944100	0.873040	0.872780	66.911200
IOP22	2.664100	2.663400	0.984910	0.984920	69.675000
IOP23	1.500400	1.499800	-0.000050	0.000040	81.025000
IOP24	1.348000	1.345400	-0.648940	-0.647280	84.516200
IOP25	0.981500	0.992100	0.000100	-0.000410	94.566200
IOPTAR	0.029000	0.028900	-0.014540	-0.022020	100.282200

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 3 to the X-ray converter target is

Table 35B
Matrix of beamline 3

-1.5559E-02	-4.0237E-03	2.9304E-02	4.2945E-06	0.	5.2143E-05
1.6342E+02	-4.5450E+00	-1.7091E+00	9.2719E+00	0.	-3.6030E-01
-1.0984E-03	-2.5899E-03	-4.5961E-02	-1.2310E-03	0.	-6.4472E-05
1.0489E+02	-5.2936E-02	5.3140E+01	-1.4422E+01	0.	6.9704E-01
-3.0799E-04	1.2165E-05	3.9121E-03	2.2780E-04	1.0000E+00	-7.0359E-01
0.	0.	0.	0.	0.	1.0000E+00

27. Beamline 4

Beamline 4 begins at point 22, figure 40__. The beam passes un-deflected by all three K90 blocks running up the line Z=8.57 meters. The beams yaw is generated by the combination of B90 and B45 blocks, with the B45 block rolled clockwise to generate the desired pitch angle.

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 51__. The beam envelope is shown in figures 41__ and 42__.

Table 36__
data.L4

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP4	2.985100	2.993400	0.018000	0.016390	15.738100
IOP5	0.398000	1.147800	-0.075240	-0.945910	22.698100
IOP7	0.759500	0.764600	0.002870	0.001040	33.248100
IOP8	3.012800	2.993300	0.949340	0.948140	42.448300
IOP15	0.591800	0.594600	0.308210	0.306920	48.498300
IOP16	3.082500	3.076500	0.332650	0.333070	60.861200
IOP21	0.945300	0.944100	0.873040	0.872780	66.911200
IOP22	2.664100	2.663400	0.984910	0.984920	69.675000
IOP27	1.764200	1.763800	0.358840	0.369320	75.725000
IOP28	1.530300	1.538400	-0.587190	-0.586810	80.248500
IOP29	1.251000	1.250500	-0.000500	-0.000100	90.298500
IOP30	1.500200	1.501100	0.286970	0.288360	96.549500
IOP31	1.501700	1.510600	0.001460	0.001690	106.949500
IOPTAR	0.022900	0.022900	-0.002670	0.000010	112.508500

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 4 to the X-ray converter target is

Table 36B
Matrix of beamline 4

2.1409E-02	8.6914E-04	-2.1563E-02	-2.7520E-03	0.	1.0631E-05
-5.5779E+01	1.0774E+01	1.7923E+02	-1.0556E+01	0.	5.4549E-02
2.0375E-02	2.8159E-03	6.7937E-04	2.0612E-03	0.	2.0953E-06
-1.8280E+02	1.0116E+01	-1.3538E+02	1.3304E-01	0.	-4.2854E-02
-1.2715E-04	2.0876E-05	2.8279E-04	1.2613E-05	1.0000E+00	-7.5664E-01
0.	0.	0.	0.	0.	1.0000E+00

28. Beamline 5

Beamline 5 begins at point 10 along beamline 1, figure 43__. KP10 is off and passes the beam through a 67.5 degree bend to index lines 5 through 8 22.5 degree from lines 1 through 4. Block KP36 kicks the beam into block B10P38 which generates the 10 degree pitch angle and on to target 5. The firing point is hit by adjusting inter-block separation IB18, IB19, and IB20.

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 52__. The beam envelope is shown in figures 44__ and 45__.

Table 37__
data.L5

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP1	0.512300	0.512300	-0.008690	-0.008690	3.327000
IOP5	0.398000	1.147800	-0.075240	-0.945910	22.698100
IOP8	3.012800	2.993300	0.949340	0.948140	42.448300
IOP9	1.510700	1.514300	-0.000690	-0.001570	53.798300
IOP10	3.067700	3.062800	0.870340	0.869210	67.248300
IOP33	1.542700	1.539600	0.489060	0.481360	73.298300
IOP34	2.239300	2.236200	0.539130	0.543630	87.673900
IOP35	0.485800	0.496700	-0.000610	0.000380	98.073900
IOP36	3.004400	2.943100	0.984420	0.983030	103.128900
IOP37	0.511000	0.475200	0.238800	-0.182530	114.478900
IOP38	0.940300	1.108800	0.305930	0.467410	119.178900
IOP39	1.032700	0.926800	0.118800	-0.112210	129.228900
IOPTAR	0.029400	0.035100	0.111980	-0.023450	134.944900

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 5 to the X-ray converter target is

Table 37B
Matrix of beamline 5

9.5776E-03	-2.1640E-03	4.6450E-02	-1.7820E-03	0.	-6.2401E-05
9.0894E+01	5.5400E-01	8.3280E+01	1.3985E+01	0.	2.8501E-01
-4.8830E-02	-3.0530E-03	-4.9901E-04	2.9235E-03	0.	-1.5294E-04
9.4545E+01	-1.0431E+01	-6.9165E+01	3.9959E-01	0.	2.4547E-01
-1.0924E-03	2.9264E-04	-7.7643E-04	-1.1447E-04	1.0000E+00	-1.2883E+00
0.	0.	0.	0.	0.	1.0000E+00

29. Beamline 6

Beamline 6 begins at point 36 of beamline 5, figure 46__. KP36 is off and passes the beam through a 90 degree bend on to block KP44 which kicks the beam into block B45P46 which generates the required pitch and yaw for target 6. The firing point is hit by adjusting inter-block separation IB22, IB23 and IB24

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 53__. The beam envelope is shown in figures 47__ and 48__.

Table 38
data.L6

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP1	0.512300	0.512300	-0.008700	-0.008700	3.327000
IOP4	2.985300	2.993300	0.017930	0.016310	15.738100
IOP5	0.398000	1.147700	-0.075350	-0.945910	22.698100
IOP8	3.012700	2.993200	0.949330	0.948120	42.448300
IOP10	3.067900	3.062800	0.870360	0.869230	67.248300
IOP33	1.542800	1.539600	0.489140	0.481410	73.298300
IOP34	2.239300	2.236300	0.539050	0.543640	87.673900
IOP35	0.485800	0.496700	-0.000580	0.000440	98.073900
IOP36	3.004200	2.943300	0.984420	0.983030	103.128900
IOP42	1.241700	1.228300	0.250640	0.214500	131.978900
IOP43	0.522300	0.469000	-0.007520	-0.013370	142.029000
IOP44	2.872400	3.177300	0.973280	0.982390	147.464400
IOP45	1.043100	1.048400	-0.037090	-0.007730	158.814600
IOP47	0.961000	1.062800	-0.085090	0.108630	176.134000
IOPTAR	0.031700	0.031800	0.008120	0.008650	182.093000

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 6 to the X-ray converter target is

Table 38B
Matrix of beamline 6

-3.6278E-02	-3.7752E-03	2.3822E-02	9.6617E-04	0.	-1.9037E-04
1.2834E+02	-1.0412E+01	-3.8696E+01	4.2131E+00	0.	1.7100E-02
1.4841E-02	-1.9661E-03	1.8861E-02	-4.5811E-03	0.	7.4648E-05
4.4553E+01	3.3795E+00	1.6804E+02	4.9015E+00	0.	2.4034E-01
-2.4119E-03	2.7681E-04	1.4934E-03	6.5337E-05	1.0000E+00	-1.7196E+00
0.	0.	0.	0.	0.	1.0000E+00

30. Beamline 7

Beamline 7 begins at point 44 of beamline 6, figure 49. KP44 is off and passes the beam through to KP50 which kicks the beam into B10P52 generate the 10 degree pitch for target 7. The firing point is hit by adjusting inter-block separation IB25, IB26 and IB27

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 54. The beam envelope is shown in figures 50 and 51.

Table 39
data.L7

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP1	0.512300	0.512300	-0.008690	-0.008690	3.327000
IOP4	2.985100	2.993400	0.018000	0.016390	15.738100
IOP5	0.398000	1.147800	-0.075240	-0.945910	22.698100
IOP8	3.012800	2.993300	0.949340	0.948140	42.448300
IOP9	1.510700	1.514300	-0.000680	-0.001560	53.798300
IOP10	3.067700	3.062800	0.870340	0.869220	67.248300
IOP34	2.239300	2.236200	0.539120	0.543630	87.673900
IOP35	0.485800	0.496700	-0.000610	0.000380	98.073900
IOP36	3.004400	2.943100	0.984420	0.983030	103.128900
IOP42	1.241800	1.228300	0.250680	0.214420	131.978900
IOP43	0.522300	0.469100	-0.007600	-0.013380	142.029000
IOP44	2.872300	3.177200	0.973280	0.982390	147.464400
IOP50	2.758500	2.857500	0.982010	0.984800	156.286600
IOP51	1.008000	1.002500	-0.001500	0.025770	167.636800
IOP53	0.979400	1.031400	-0.054200	0.017550	181.852600
IOPTAR	0.031900	0.034100	0.042880	0.039800	187.572600

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 7 to the X-ray converter target is

Table 39B
Matrix of beamline 7

3.0503E-02	-2.9203E-03	1.8716E-03	3.7318E-03	0.	-3.1466E-05
9.3044E+01	7.1243E+00	-1.3633E+02	1.1743E+00	0.	5.4396E-01
3.6657E-02	-2.8632E-03	3.3273E-03	-3.8983E-03	0.	5.9517E-05
7.9462E+01	7.7325E+00	1.2541E+02	4.4657E-02	0.	-1.9753E-01
-7.5524E-04	1.2558E-04	1.1440E-03	-2.8354E-04	1.0000E+00	-1.6247E+00
0.	0.	0.	0.	0.	1.0000E+00

31. Beamline 8

Beamline 8 begins at point 50 of beamline 7, figure 52. KP50 is off and passes the beam through blocks B90P56 and B45P58 generating the required yaw and pitch for target 8. The firing point is hit by adjusting inter-block separations IB28, IB29, and IB30.

The transport data for this beamline, starting at the accelerator exit and extending to the firing point is given in table 55. The beam envelope is shown in figures 53 and 54.

Table 40__
data.L8

Name	x(cm)	y(cm)	r21	r43	Lc(meters)
IOP1	0.512300	0.512300	-0.008690	-0.008690	3.327000
IOP8	3.012800	2.993300	0.949340	0.948130	42.448100
IOP10	3.067700	3.062900	0.870330	0.869230	67.248100
IOP34	2.239300	2.236100	0.539090	0.543590	87.673700
IOP35	0.485800	0.496700	-0.000630	0.000400	98.073700
IOP36	3.004300	2.943100	0.984420	0.983030	103.128700
IOP42	1.241800	1.228300	0.250720	0.214460	131.978700
IOP43	0.522300	0.469100	-0.007610	-0.013350	142.028800
IOP44	2.872200	3.177300	0.973280	0.982390	147.464200
IOP50	2.758500	2.857400	0.982010	0.984800	156.286400
IOP56	2.313900	2.260000	0.359150	0.265080	166.865300
IOP57	1.012900	1.002400	-0.003800	-0.001240	176.915500
IOP58	1.336200	1.365400	0.370930	0.328400	183.842900
IOP59	0.993200	1.046000	0.027430	-0.033070	194.243200
IOPTAR	0.034500	0.032000	-0.058550	0.090130	199.803200

The linear transformation matrix from the exit of the accelerator, through all blocks of beamline 8 to the X-ray converter target is

Table 40B
Matrix of beamline 8

-4.6430E-02	-6.2993E-04	2.5657E-02	3.5896E-03	0.	-1.9233E-04
2.8376E+01	-1.0018E+01	-1.0527E+02	5.4224E+00	0.	2.5915E-02
-4.1398E-02	-1.5161E-03	-1.3692E-02	-3.6428E-03	0.	-7.6020E-06
4.3403E+01	-1.0899E+01	1.1484E+02	-4.7227E+00	0.	-6.1623E-02
-7.1570E-04	1.9302E-04	1.7870E-03	-1.3222E-04	1.0000E+00	-1.6779E+00
0.	0.	0.	0.	0.	1.0000E+00

32. Yet Reborn Again

Lets consider what we might do differently if we had to revisit the design of the diagnostic X beamline from the start. ah yes, as I have done already several times.

- 1 The decision to use bends based on four fold symmetry was driven by concerns about adverse effects of large beam flutter in a space charge environment. Should these concerns be unwarranted, the total system size and magnet count could be reduced by use of DQD achromatic systems, figure 5__ with a larger allowed flutter.
- 2 The scaling laws outlines in section 6 might be altered to reduce the overall size without increasing the beam aberrations and emittance. This issue would required detailed analysis of different magnet designs far in excess of the time and effort invested in this work to date.

Table 41
TRANSPORT data for the 10 degree achromatic bend system.

DATA	comments
10 deg achromatic bend	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/C 0.001	Momentum in MeV/C
16 3 1	restmass - 1 electron
16 4 8	default horizontal bend 1/2 aperture
16 5 8	default vertical bend 1/2 aperture
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
22 0 0 0 0 1	1% off energy centroid vector
24 0 9 9	plot scale 9cm
1 1.5 2 1.5 2 0 0 20.5044	beam
12 0 r15	correlations
-26 0.01 2000	space charge
6 7 8 19	plot scale for solenoid
6 7 8 4	plot scale for bends
3 2	2 meter drift
20 90	rotate (roll) 90 degree - bend down
5 0.2 -3.0 100 q1	entrance matching quad
3 0.2	
5 0.2 -4.0 100 q2	entrance matching quad
3 0.25	
5 0.2 3.3 100 q3	entrance matching quad
3 0.2	
5 0.2 -5.5 100 q4	entrance matching quad
3 0.75	
9 3	repeat 3 times
5 0.2 8.28944 100 qd	achromatic quad pi/2 phase advance
3 0.2	
2 1.25 0	vertical edge fringe focusing
4 0.5 0.059687 0 bml	bend magnet
2 1.25 0	vertical edge fringe focusing
3 0.2	
5 0.2 -8.2406 100 qf	achromatic quad pi/2 phase advance
3 0.2	
9 0	end repeat
5 0.2 8.28944 100 qd	start fourth cell
3 0.2	
2 1.25 0	
4 0.5 0.059687 0 bml	fourth bend magnet
2 1.25 0	
3 0.2	
5 0.2 -6.0 100 qfx	last "achro" quad tuned for phase space acceptance
3 0.2	<--- end fourth cell
3 0.4	
5 0.2 -1.2564 100 q5	exit matching quad
3 0.2	
5 0.2 6.6427 100 q6	exit matching quad
3 0.2	
5 0.2 -3.6742 100 q7	exit matching quad
3 0.2	
5 0.2 -1.1006 100 q8	exit matching quad
20 -90	un-roll
3 1.5	drift 1.5 meters
13 1	beam round. at waist, r=1.5cm
72	end data case
73	end all data

Table 42
TRANSPORT data for the 45 degree achromatic bend system.

DATA	comments
45 deg achromatic bend	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/C 0.001	Momentum in MeV/C
16 3 1	restmass - 1 electron
16 4 8	default horizontal bend 1/2 aperture
16 5 8	default vertical bend 1/2 aperture
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
22 0 0 0 0 1	1% off energy centroid vector
24 0 9 9	plot scale 9cm
1 1.5 2 1.5 2 0 0 20.5044	beam
12 0r15	correlations
-26 0.01 2000	space charge
6 7 8 4	plot scale for bends
3 2.0	2 meter drift
-20 14.0	roll to generate pitch and yaw
5 0.2 -3.0 100 q1	entrance matching quad
3 0.2	
5 0.2 4.0 100 q2	entrance matching quad
3 0.6	
5 0.2 3.3 100 q3	entrance matching quad
3 0.2	
5 0.2 -5.5 100 q4	entrance matching quad
3 0.75	
9 4	repeat 3 times
5 0.2 8.55949 100 qd4	achromatic quad pi/2 phase advance
3 0.2	
2 5.675 0	vertical edge fringe focusing
4 0.5 0.27540 0 bm22	bend magnet
2 5.675 0	vertical edge fringe focusing
3 0.2	
5 0.2 -9.25698 100 qi4	achromatic quad pi/2 phase advance
3 0.2	
9 0	end repeat
3 0.4	
5 0.2 7.0702 100 q5	exit matching quad
3 0.2	
5 0.2 -6.0112 100 q6	exit matching quad
3 0.25	
5 0.2 -2.7502 100 q7	exit matching quad
3 0.2	
5 0.2 2.7753 100 q8	exit matching quad
3 1.5	drift 1.5 meters
13 1	beam round. at waist, r=1.5cm
73	end data case
73	end all data

Table 43
TRANSPORT data for the 67.5 degree achromatic bend system.

DATA	comments
67.5 deg achromatic bend	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/C 0.001	Momentum in MeV/C
16 3 1	restmass - 1 electron
16 4 4	default horizontal bend 1/2 aperture
16 5 4	default vertical bend 1/2 aperture
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
22 0 0 0 0 1	1% off energy centroid vector
24 0 9 9	plot scale 9cm
1 1.5 2 1.5 2 0 0 20.5044	beam
12 0r15	correlations
-26 0.01 2000	space charge
6 7 8 19	plot scale for solenoid
6 7 3 4	plot scale for bends
3 2	2 meter drift
5 0.2 -3.0 100 q1	entrance matching quad
3 0.2	
5 0.2 4.0 100 q2	entrance matching quad
3 0.6	
5 0.2 3.3 100 q3	entrance matching quad
3 0.2	
5 0.2 -5.5 100 q4	entrance matching quad
3 0.75	
9 4	repeat 4 times
5 0.2 8.57220 100 qd	achromatic quad pi/2 phase advance
3 0.2	
2 -8.4375 0	vertical edge fringe focusing
4 0.5 -0.402886 0 bmb	bend magnet
2 -8.4375 0	vertical edge fringe focusing
3 0.2	
5 0.2 -9.2540 100 qi	achromatic quad pi/2 phase advance
3 0.2	
9 0	end repeat
3 0.4	
5 0.2 7.1342 100 q5	exit matching quad
3 0.2	
5 0.2 -6.4502 100 q6	exit matching quad
3 0.2	
5 0.2 -2.1615 100 q7	exit matching quad
3 0.2	
5 0.2 2.5845 100 q8	exit matching quad
3 2.0	drift 2 meters
13 1	beam round, at waist, r=1.5cm
73	end data case
73	end all data

Table 44
TRANSPORT data for the 90 degree achromatic bend system.

DATA	comments
90 deg achromatic bend	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/C 0.001	Momentum in MeV/C
16 3 1	restmass - 1 electron
16 4 8	default horizontal bend 1/2 aperture
16 5 8	default vertical bend 1/2 aperture
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
22 0 0 0 0 1	1% off energy centroid vector
24 0 9 9	plot scale 9cm
1 1.5 2 1.5 2 0 0 20.5044	beam
12 0r15	correlations
-26 0.01 2000	space charge
6 7 8 19	plot scale for solenoid
6 7 8 4	plot scale for bends
3 2	2 meter drift
5 0.2 -4.0 100 q1	entrance matching quad
3 0.2	
5 0.2 -4.5 100 q2	entrance matching quad
3 0.4	
5 0.2 -4.3 100 q3	entrance matching quad
3 0.2	
5 0.2 -6.5 100 q4	entrance matching quad
3 0.6	
9 3	repeat 3 times
5 0.2 8.58472 100 qd	achromatic quad pi/2 phase advance
3 0.2	
2 11.25 0	vertical edge fringe focusing
4 0.5 0.537182 0 bm9	bend magnet
2 11.25 0	vertical edge fringe focusing
3 0.2	
5 0.2 -9.23702 100 qf	achromatic quad pi/2 phase advance
3 0.2	
9 0	end repeat
5 0.2 8.58472 100 qd	start last cell 4
3 0.2	
2 11.25 0	
4 0.5 0.537182 0 bm9	bend cell 4
2 11.25 0	
3 0.2	
5 0.2 -4.0 100 qfx	cell 4 quad tuned
3 0.6	
5 0.2 5.8798 100 q5	exit matching quad
3 0.2	
5 0.2 -4.7422 100 q6	exit matching quad
3 0.2	
5 0.2 1.4441 100 q7	exit matching quad
3 0.2	
5 0.2 0.2519 100 q8	exit matching quad
13 1	beam round. at waist. r=1.5cm
3 1.5	drift 1.5 meters
73	end data case
73	end all data

Table 45
TRANSPORT data for the 90 degree kicker achromatic bend system.

DATA	comments
90 deg kicker septum achromatic	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/C 0.001	Momentum in MeV/C
16 3 1	restmass - 1 electron
16 4 8	default horizontal bend 1/2 aperture
16 5 8	default vertical bend 1/2 aperture
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
22 0 0 0 0 1	1% off energy centroid vector
24 0 9 9	plot scale 9cm
1 1.05 6.5547 1.05 6.5547 0 0 20.5044	beam
12 0r15	correlations
-26 0.01 2000	space charge
6 7 8 19	plot scale for solenoid
6 7 8 4	plot scale for bends
3 3.1	3.1 meter drift
19 0.2 2.0 s3	kicker match solenoid
3 0.25	
6 0 1	update RC() matrix
4 1.4 0.008527 0 kicker	1 degree kicker bias dipole
3 2.5	2.5 meter drift to septum
2 10.525	edge focusing
4 0.5 0.513307 0 bm21	21.5 degree septum dipole
2 10.525	edge focusing
3 0.2	
9 3	repeat 3 times
5 0.2 -6.7596 100 qd4	achromatic quad pi/2 phase advance
3 0.2	
5 0.2 7.6651 100 qf4	achromatic quad pi/2 phase advance
3 0.2	
2 11.25 0	vertical edge fringe focusing
4 0.5 0.337182 0 bm22	bend magnet
2 11.25 0	vertical edge fringe focusing
3 0.2	
9 0	end repeat
3 0.4	
5 0.2 -1.5613 100 qd5	exit matching quad
3 0.2	
5 0.2 2.7088 100 qd6	exit matching quad
3 0.2	
5 0.2 -5.7093 100 qd7	exit matching quad
3 0.2	
5 0.2 4.2255 100 qd8	exit matching quad
13 1	beam round at waist, r=1.5cm
3 1.5	drift 1.5 meters
73	end data case
73	end all data

Table 46
TRANSPORT data for the 90 degree accelerator break-out

DATA	comments
90 deg accelerator break-out	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/C 0.001	Momentum in MeV/C
16 3 1	restmass - 1 electron
16 4 8	default horizontal bend 1/2 aperture
16 5 8	default vertical bend 1/2 aperture
16 6 -0.8510	starting longitudinal path length
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
24 0 14 14	plot scale
24 8 0 0 -0.8510	starting global coordinates
1 0.5 6.0 0.5 6.0 0 0 20.5044	the beam
-26 0.01 2000.0	space charge
6 7 12.7 19	solenoid plotting aperture
19 4.178 1.6009 accel	A little bit of the Accelerator
3 0.1111	
13 1	output the beam
6 7 8.5 19.	
19 0.25 0 s0	Solenoid S0
3 0.2	
20 -10.0	roll 10 degrees
6 0 1	
5 0.2 10.0 100 q1	match into the 90d bend system
3 0.2	
5 0.2 -10.0 100 q2	match into the 90d bend system
3 0.4	
9 3	repeat 3 times
5 0.2 8.17775 100 qf	qf,qd pi/2 phase advance for achromatic bend
3 0.2	
2 -11.25	fringe field and bend magnets
4 0.5 -0.537182 0 bml	for cells 1, 2, and 3
2 -11.25	each dipole bends by 22.5 degrees
3 0.2	
5 0.2 -7.71653 100 qd	qf,qd pi/2 phase advance for achromatic bend
3 0.2	
9 0	end repeat
5 0.2 8.17775 100 qf	<---- start cell 4
3 0.2	
2 -11.25	fringe field and bend magnet
4 0.5 -0.537182 0 bml	for cell 4. Last quadrupole qd4
2 -11.25	set different than cells 1-3.
3 0.2	
5 0.2 -1.2 100 qd4	<---- end cell 4
13 1	output beam
3 2.6	
5 0.2 -1.0598 100 q5	exit match quadrupole
3 0.2	
5 0.2 0.4111 100 q6	exit match quadrupole
3 0.25	
5 0.2 3.1028 100 q7	exit match quadrupole
3 0.2	
5 0.2 -2.3582 100 q8	exit match quadrupole
3 1	drift B2
19 0.25 1.34 s3	solenoid S3 matches beam to the kicker
3 0.25	
4 1.4 0 0 kicker	The kicker on - cancels bias dipole, 0 degrees
3 2.5	
16 16 0.19	38 cm full bore on quadrupole septum
5 0.51 -4.5 100 qseptm	quadrupole septum - beam on center line
3 0.25	
16 16 0.06	12 cm bore on Collins quadrupoles
5.00 0.25 6.0 100 qxh	Collins quad qxh
3 0.8	
5.00 0.25 -5.0 100 qxv	Collins quad qxv
3 0.25	
5.00 0.25 2.6 100 qxw	Collins quad qxw
13 1 ion5	point 5 figure 2
3 0.5	
13 1 ion6	point 5 figure 2
73	

Table 47
TRANSPORT data for the kicker quadrupole septum beam dump

DATA	comments
45d kicker quad septum - dump beamline	
0	
13 2.1	suppress verbose output to output file
15 11 MeV/c 0.001	Momentum in MeV/c
16 3 1	restmass - 1 electron
16 4 3	default horizontal bend 1/2 aperture
16 5 3	default vertical bend 1/2 aperture
16 6 -0.8510	starting longitudinal path length
16 16 0.08	scale quadrupole aperture (100x0.08=8cm)
13 12	initial global coordinate calculation
24 0 10 10	plot scale
24 3 0 0 -0.8510	starting global coordinates
1 3.0 1.0 3.0 1.0 0 0 20.5044	the beam
12 0r15	phase space correlations
6 7 8.0 4	default bend magnet plot aperture
6 7 7 19	default solenoid plot aperture
3 1	drift 1 meter
<hr/>	
13 1 iop4	point 4
19 0.25 1.34 s3	solenoid match to kicker
3 0.25	drift
4 1.400 0 0 kicker	kicker - off, field cancelled
3 2.5	drift to septum
16 16 0.19	set quad aperture
5 0.51 -4.5 100 qseptm	quadrupole septum
3 0.25	drift
16 16 0.06	set Collins quad aperture
5 0.25 6.0 100 cqh	Collins quad
3 0.8	
5 0.25 -5.0 100 cqv	Collins quad
3 0.25	
5 0.25 2.6 100 cqw	Collins quad
13 1 iop5	point 5, end of kqs
3 0.5	1B3
13 1 iop6	start block b10-06
73.	end of data

Table 48
Transport data file: data.L1

DiagX Line 1 (DX124)				
0				
15 11 MeV/C 0.001				
13 2.1	5 0.2 -1.2 100 qx9p02	3 0.2	3 0.4	3 2.338
16 3 1	3 0.2	4 0.5 -0.059687 0 bmlp06	5 0.2 5.50625 100 qlp08	19 0.2 1.4 ss06a
16 6 -0.851	3 2.4	3 0.2	3 0.2	3 1.75129 lvx01
16 16 0.08	5 0.2 -1.0598 100 q5p02	5 0.2 -8.2406 100 qrlp06	5 0.2 -8.27972 100 q2p08	13 1 iop12
16 29 -1	3 0.2	3 0.2	3 0.2	20 90
24 0 9 0 0 0	5 0.2 0.4111 100 q6p02	9 0	5 0.2 4.82671 100 q3p08	5 0.2 -3 100 qlp12
13 12	3 0.25	3 0.4	3 0.2	3 0.2
24 8 0 0 -0.851 0 0	5 0.2 3.1038 100 q7p02	5 0.2 7.2323 100 q5p06	5 0.2 0.06473 100 q4p08	5 0.2 4 100 q2p12
22 0	3 0.2	3 0.2	13 1 iop9	3 0.6
1 0.5 6 0.5 6 0 0 20.5044 beam1	5 0.2 -2.3582 100 q8p02	5 0.2 -0.6458 100 q6p06	3 3.5	5 0.2 3.3 100 q3p12
12 0 0 0 0 0 0 0 0 0 0 0 0	13 1 iop3	3 0.25	19 0.2 0 sli05	3 0.2
6 7 8 4	3 1 lxx	5 0.2 -7.3263 100 q7p06	3 3.5	5 0.2 -5.5 100 q4p12
6 6 12 12	13 1 iop4	3 0.2	19 0.2 0 s2i05	3 0.4
6 7 12.7 19	19 0.25 1.34 s3p04	5 0.2 4.1652 100 q8p06	3 3.5	9 4
19 4.178 1.6009 1703x	3 0.25	13 1 iop7	19 0.2 0 s3i05	5 0.2 8.28944 100 qd1p12
13 1 iop1	4 1.4 0 0 kqs	20 -90	3 2.35 lvz01	3 0.2
3 0.1111	3 1	3 1	13 1 iop10	4 0.5 0.059687 0 bmlp12
6 7 8.5 19	3 0.5	3 1	19 0.2 1.7 s3p10	3 0.2
19 0.25 0 ss0	3 0.5	19 0.2 1 sli04	3 0.25	5 0.2 -8.2406 100 qrlp12
20 -10	3 0.5	3 2	4 1.4 -0.008527 0 kp10	3 0.2
3 0.2	16 16 0.19	19 0.2 0 s2i04	3 2.5	9 0
13 1 iop2	5 0.51 -4.5 100 qseptm	3 2	2 -10.525 0	3 0.4
5 0.2 10 100 qlp02	3 0.25	19 0.2 0 s3i04	4 0.5 -0.513307 0 bsep10	5 0.2 5.989635 100 q5p12
3 0.2	16 16 0.06	3 2	2 -10.525 0	3 0.2
5 0.2 -10 100 q2p02	5 0.25 6 100 qxh	3 0.6002	3 0.2	5 0.2 -0.731375 100 q6p12
3 0.2	3 0.8	13 1 iop8	9 3	3 0.25
3 0.2	5 0.25 -5 100 qxv	19 0.2 1.6 s3p08	5 0.2 -6.3329 100 qrlp10	5 0.2 -4.73679 100 q7p12
9 3	3 0.25	3 0.25	3 0.2	3 0.2
5 0.2 8.17775 100 qrlp02	5 0.25 2.6 100 qxw	4 1.4 0.008527 0 kp08	5 0.2 7.5243 100 qd9p10	5 0.2 2.58296 100 q8p12
3 0.2	16 16 0.08	3 2.5	3 0.2	13 1 iop13
2 -11.25 0	13 1 iop5	2 10.525 0	2 -11.25 0	3 1.5
4 0.5 -0.537182 0 bmlp02	3 0.5 lxx	4 0.5 0.513307 0 bsep08	4 0.5 -0.537182 0 bmlp10	19 0.2 1.6 sn07
2 -11.25 0	13 1 iop6	2 10.525 0	2 -11.25 0	3 3.36755 lvx1
3 0.2	20 90	3 0.2	3 0.2	19 0.05 18.07 sif1
5 0.2 -7.71653 100 qd9p02	5 0.2 -8 100 qlp06	9 3	9 0	3 0.1
3 0.2	3 0.2	5 0.2 -6.3329 100 qrlp08	3 0.4	13 1 ioptar
9 0	5 0.2 4 100 q2p06	3 0.2	5 0.2 5.8284 100 qlp10	3 2 firepnt
5 0.2 8.17775 100 qrlp02	3 0.6	5 0.2 7.5243 100 qd9p08	3 0.2	13 1 iorfp
3 0.2	5 0.2 6 100 q3p06	3 0.2	5 0.2 -8.4725 100 q2p10	21 8 2 200
2 -11.25 0	3 0.2	2 11.25 0	3 0.2	21 5 5 500
4 0.5 -0.537182 0 bmlp02	5 0.2 -8.5 100 q4p06	4 0.5 0.537182 0 bmlp08	5 0.2 6.5989 100 q3p10	
2 -11.25 0	3 0.4	2 11.25 0	3 0.2	
3 0.2	9 4	3 0.2	5 0.2 -0.3062 100 q4p10	
5 0.2 -1.2 100 qx9p02	5 0.2 8.28944 100 qd1p06	9 0	13 1 iop11	

Table 49
Transport data file: data.L2

DiagX Line 2 (DX124)				
0				
15 11 MeV/C 0.001				
13 2.1	3 0.2	5 0.2 7.2323 100 q1p06	19 0.2 0 s4i08	5 0.2 -3 100 q1p18
16 3 1	5 0.2 0.4111 100 q6p02	3 0.2	3 1	3 0.2
16 6 -0.851	3 0.25	5 0.2 -0.6458 100 q1p06	3 1.76292 lxx02	5 0.2 4 100 q2p18
16 16 0.08	5 0.2 3.1038 100 q7p02	3 0.25	13 1 iop16	3 0.6
16 29 -1	3 0.2	5 0.2 -7.3263 100 q1p06	19 0.2 1.44 s3p16	5 0.2 3.3 100 q3p18
24 0 9 9 0 0 0	5 0.2 -2.3582 100 q8p02	3 0.2	3 0.25	3 0.2
13 12	3 1 lxx	5 0.2 4.1632 100 q1p06	4 1.4 0.008527 0 kp16	5 0.2 -5.5 100 q4p18
24 8 0 0 -0.851 0 0	13 1 iop4	20 -90 rol03	3 1	3 0.75
1 0.5 6 0.5 6 0 0 20.5044 beam1	19 0.25 1.34 s3p04	13 1 iop7	3 0.5	9 4
12 0 0 0 0 0 0 0 0 0 0 0 0	3 0.25	3 1	3 0.5	5 0.2 8.4326 100 qd4p18
6 7 8 4	4 1.4 0 0 kqs	3 1	3 0.5	3 0.2
6 6 12 12	3 1	19 0.2 1 sli04	2 10.525 0	4 0.5 -0.27376 0 bm4p18
6 7 12.7 19	3 0.5	3 1	4 0.5 0.513307 0 bsep16	3 0.2
19 4.178 1.6009 1703x	3 0.5	3 1	2 10.525 0	5 0.2 -9.2843 100 qf4p18
3 0.1111	3 0.5	19 0.2 0 s2i04	3 0.2	3 0.2
6 7 8.5 19	16 16 0.19	3 1	9 3	9 0
19 0.25 0 ss0	5 0.51 -4.5 100 qseptm	3 1	5 0.2 -6.3329 100 qf9p16	3 0.4
20 -10 rol01	3 0.25	19 0.2 0 s3i04	3 0.2	5 0.2 6.6359 100 q5p18
3 0.2	16 16 0.06	3 1	5 0.2 7.5243 100 qd9p16	3 0.2
5 0.2 10 100 q1p02	5 0.25 6 100 qxh	3 1	3 0.2	5 0.2 -4.3666 100 q6p18
3 0.2	3 0.8	3 0.6002	2 11.25 0	3 0.25
5 0.2 -10 100 q2p02	5 0.25 -5 100 qxv	13 1 iop8	4 0.5 0.537182 0 bm9p16	5 0.2 -4.0769 100 q7p18
3 0.4	3 0.25	19 0.2 1.6 s3p08	2 11.25 0	3 0.2
9 3	5 0.25 2.6 100 qxw	3 0.25	3 0.2	5 0.2 2.9502 100 q8p18
5 0.2 8.17775 100 qf9p02	16 16 0.08	4 1.4 0 0 kp08	9 0	13 1 iop19
3 0.2	13 1 iop5	3 1	3 0.4	3 1.5
2 -11.25 0	3 0.5 lxx	3 0.5	5 0.2 6.6555 100 q1p16	19 0.2 0.8 sti10
4 0.5 -0.537182 0 bm9p02	20 90 rol02	3 0.5	3 0.2	3 2.1922 lvyx2
2 -11.25 0	5 0.2 -8 100 q1p06	3 0.5	5 0.2 -7.2937 100 q2p16	3 0.5
3 0.2	3 0.2	4 0.5 0 0 bsep08	3 0.2	3 0.5
5 0.2 -7.71653 100 qd9p02	5 0.2 4 100 q1p06	3 0.5	5 0.2 0.5241 100 q3p16	3 0.5
3 0.2	3 0.6	3 0.5	3 0.2	19 0.05 17.9 sif2
9 0	5 0.2 6 100 q1p06	19 0.2 0 sli08	5 0.2 3.3175 100 q4p16	3 0.1
5 0.2 8.17775 100 qf9p02	3 0.2	13 1 iop15	13 1 iop17	13 1 ioptar
3 0.2	5 0.2 -8.5 100 q1p06	3 1	3 1	3 2 firepnt
2 -11.25 0	3 0.4	3 1	3 0.5	13 1 iofp
4 0.5 -0.537182 0 bm9p02	9 4	3 1	3 0.5	21 8 2 200
2 -11.25 0	5 0.2 8.28944 100 qd1p06	19 0.2 1 s2i08	3 1	21 8 5 500
3 0.2	3 0.2	3 1	19 0.2 0 sli09	
5 0.2 -1.2 100 qx9p02	4 0.5 -0.059687 0 bmlp06	3 1	3 1	
3 0.2	3 0.2	3 1	3 1	
3 1.4	5 0.2 -8.2406 100 qf1p06	19 0.2 1 s3i08	19 0.2 1 s2i09	
3 1	3 0.2	3 1	3 1.2522 lxx02	
5 0.2 -1.0598 100 q5p02	9 0	3 1	13 1 iop18	
3 0.2	3 0.4	3 1	20 -14.02 rol45	

Table 50
Transport data file: data.L3

DiagX Line 3				
0				
15 11 MeV/C 0.001				
13 2.1	3 0.25	5 0.2 -7.3263 100 q7p06	3 1	13 1 iop24
16 3 1	5 0.2 3.1038 100 q7p02	3 0.2	3 0.5	20 90
16 6 -0.851	3 0.2	5 0.2 4.1652 100 q8p06	3 0.5	5 0.2 -3 100 q1p24
16 16 0.08	5 0.2 -2.3582 100 q8p02	20 -90 roi03	3 0.5	3 0.2
16 29 -1	13 1 iop3	13 1 iop7	4 0.5 0 0 bsep16	5 0.2 4 100 q2p24
24 0 9 9 0 0 0	3 1 lxx	3 1	3 0.5	3 0.6
13 12	13 1 iop4	3 1	3 0.5	5 0.2 3.3 100 q3p24
24 8 0 0 -0.851 0 0	19 0.25 1.34 s3p04	19 0.2 1 sli04	19 0.2 0 s4p16	3 0.2
1 0.5 6 0.5 6 0 0 20.5044 beam1	3 0.25	3 1	13 1 iop21	5 0.2 -5.5 100 q4p24
12 0 0 0 0 0 0 0 0 0 0 0 0 0 0	4 1.4 0 0 kas	3 1	3 2.7638 lxx03	3 0.4
6 7 8 4	3 1	19 0.2 0 s2i04	13 1 iop22	9 4
6 6 12 12	3 0.5	3 1	19 0.2 2.2 s3p22	5 0.2 8.28944 100 qd1p24
6 7 12.7 19	3 0.5	3 1	3 0.25	3 0.2
19 4.178 1.6009 J703x	3 0.5	19 0.2 0 s3i04	4 1.4 0.008527 0 kp22	4 0.5 0.059687 0 bmlp24
3 0.1111	16 16 0.19	3 1	3 1	3 0.2
6 7 8.5 19	5 0.51 -4.5 100 qseptm	3 1	3 0.5	5 0.2 -8.2406 100 qf1p24
19 0.25 0 ss0	3 0.25	3 0.6002	3 0.5	3 0.2
20 -10 roi01	16 16 0.06	13 1 iop8	3 0.5	9 0
3 0.2	5 0.25 6 100 qxh	19 0.2 1.6 s3p08	2 10.525 0	3 0.4
13 1 iop2	3 0.8	3 0.25	4 0.5 0.513307 0 bsep22	5 0.2 6.46505 100 q5p24
5 0.2 10 100 q1p02	5 0.25 -5 100 qxv	4 1.4 0 0 kp08	2 10.525 0	3 0.2
3 0.2	3 0.25	3 1	3 0.2	5 0.2 -0.90688 100 q6p24
5 0.2 -10 100 q2p02	5 0.25 2.6 100 qxw	3 0.5	9 3	3 0.25
3 0.4	16 16 0.08	3 0.5	5 0.2 -6.3329 100 qf9p22	5 0.2 -4.81089 100 q7p24
9 3	13 1 iop5	3 0.5	3 0.2	3 0.2
5 0.2 8.17775 100 qf9p02	3 0.5 lxx	4 0.5 0 0 bsep08	5 0.2 7.5243 100 qd9p22	5 0.2 2.40125 100 q8p24
3 0.2	20 90 roi02	3 0.5	3 0.2	20 -90
2 -11.25 0	5 0.2 -8 100 q1p06	3 0.5	2 11.25 0	13 1 iop25
4 0.5 -0.537182 0 bmlp02	3 0.2	19 0.2 0 sli08	4 0.5 0.537182 0 bmlp22	3 0.5
2 -11.25 0	5 0.2 4 100 q2p06	13 1 iop15	2 11.25 0	3 1
3 0.2	3 0.6	3 1	3 0.2	19 0.2 1.4 sti13
5 0.2 -7.71653 100 qd9p02	5 0.2 6 100 q3p06	3 1	9 0	3 2.366 lvyz3
3 0.2	3 0.2	3 1	3 0.4	3 0.5
9 0	5 0.2 -8.5 100 q4p06	19 0.2 1 s2i08	5 0.2 1.76053 100 q1p22	3 0.5
5 0.2 8.17775 100 qf9p02	3 0.4	3 1	3 0.2	3 0.5
3 0.2	9 4	3 1	5 0.2 -5.40984 100 q2p22	19 0.05 18.02441 sti5
2 -11.25 0	5 0.2 8.28944 100 qd1p06	3 1	3 0.2	3 0.1
4 0.5 -0.537182 0 bmlp02	3 0.2	19 0.2 1 s3i08	5 0.2 7.85863 100 q3p22	13 1 ioptar
2 -11.25 0	4 0.5 -0.059687 0 bmlp06	3 1	3 0.2	3 2 firepnt
3 0.2	3 0.2	3 1	5 0.2 -2.93425 100 q4p22	13 1 iofp
5 0.2 -1.2 100 qx9p02	5 0.2 -8.2406 100 qf1p06	3 1	13 1 iop23	21 3 2 200
3 0.2	3 0.2	19 0.2 0 s4i08	3 0.5	21 3 5 500
3 1.4	9 0	3 1	3 0.5	
3 1	3 0.4	3 1.76292 lxx02	3 0.5	
5 0.2 -1.0598 100 q5p02	5 0.2 7.2323 100 q5p06	13 1 iop16	3 0.7912 lxx03	
3 0.2	3 0.2	19 0.2 1.44 s3p16	19 0.2 1.3 sti12	
5 0.2 0.4111 100 q6p02	5 0.2 -0.6458 100 q6p06	3 0.25	3 0.5	
3 0.25	3 0.25	4 1.4 0 0 kp16	3 0.5	

Table 51
Transport data file: data.L4

DiagX Line 4				
0				
15 11 MeV/C 0.001				
13 2.1	3 1 ixx	3 1	19 0.2 2.2 s3p22	3 1
16 3 1	13 1 iop4	3 1	3 0.25	3 1
16 6 -0.851	19 0.25 1.34 s3p04	19 0.2 0 s2i04	4 1.4 0 0 kp22	19 0.2 0 s2i15
16 16 0.08	3 0.25	3 1	3 1	3 0.851 lvz04
16 29 -1	4 1.4 0 0 kqs	3 1	3 0.5	13 1 iop30
24 0 9 9 0 0 0	3 1	19 0.2 0 s3i04	3 0.5	20 14.002 rot45
13 12	3 0.5	3 1	3 0.5	5 0.2 2 100 q1p30
24 8 0 0 -0.851 0 0	3 0.5	3 1	4 0.5 0 0 bsep22	3 0.2
1 0.5 6 0.5 6 0 0 20.5044 beam1	3 0.5	3 0.6002	3 0.5	5 0.2 -4 100 q2p30
12 0 0 0 0 0 0 0 0 0 0 0 0 0 0	16 16 0.19	13 1 iop8	3 0.5	3 0.6
6 7 8 4	5 0.51 -4.5 100 qseptm	19 0.2 1.6 s3p08	19 0.2 1.9 s4p22	5 0.2 7.3 100 q3p30
6 6 12 12	3 0.25	3 0.25	13 1 iop27	3 0.2
6 7 12.7 19	16 16 0.06	4 1.4 0 0 kp08	3 0.5	5 0.2 -5.5 100 q4p30
19 4.178 1.6009 J703x	5 0.25 6 100 qxh	3 1	3 0.5	3 0.75
3 0.1111	3 0.8	3 0.5	3 0.5	9 4
6 7 8.5 19	5 0.25 -5 100 qxv	3 0.5	3 0.5	5 0.2 8.434044 100 qd4p30
19 0.25 0 ss0	3 0.25	3 0.5	19 0.2 1.17 s1i14	3 0.2
20 -10 rot01	5 0.25 2.6 100 qxw	4 0.5 0 0 bsep08	3 1	4 0.5 0.27375 0 bm4p30
3 0.2	16 16 0.08	3 0.5	3 1.3235 lvx04	3 0.2
5 0.2 10 100 q1p02	13 1 iop5	3 0.5	13 1 iop28	5 0.2 -9.284009 100 qf4p30
3 0.2	3 0.5 ixx	19 0.2 0 s1i08	5 0.2 -3 100 q1p28	3 0.2
5 0.2 -10 100 q2p02	20 90 rot02	13 1 iop15	3 0.2	9 0
3 0.4	5 0.2 -8 100 q1p06	3 1	5 0.2 5 100 q2p28	3 0.4
9 3	3 0.2	3 1	3 0.6	5 0.2 7.6784 100 q5p30
5 0.2 8.17775 100 qf9p02	5 0.2 4 100 q2p06	3 1	5 0.2 0 100 q3p28	3 0.2
3 0.2	3 0.6	19 0.2 1 s2i08	3 0.2	5 0.2 -7.4544 100 q6p30
2 -11.25 0	5 0.2 6 100 q3p06	3 1	5 0.2 -5 100 q4p28	3 0.25
4 0.5 -0.537182 0 bm9p02	3 0.2	3 1	3 0.4	5 0.2 -1.0834 100 q7p30
2 -11.25 0	5 0.2 -8.5 100 q4p06	3 1	9 4	3 0.2
3 0.2	3 0.4	19 0.2 1 s3i08	5 0.2 8.58472 100 qd9p28	5 0.2 1.9619 100 q8p30
5 0.2 -7.71653 100 qd9p02	9 4	3 1	3 0.2	13 1 iop31
3 0.2	5 0.2 8.28944 100 qd1p06	3 1	2 11.25 0	3 0.5
9 0	3 0.2	3 1	4 0.5 0.537182 0 bm9p28	3 1
5 0.2 8.17775 100 qf9p02	4 0.5 -0.059687 0 bmlp06	19 0.2 0 s4i08	2 11.25 0	19 0.2 0.6 sti16
3 0.2	3 0.2	3 1	3 0.2	3 2.209 lvya4
2 -11.25 0	5 0.2 -8.2406 100 qf1p06	3 1.76292 lvx02	5 0.2 -9.23702 100 qf9p28	3 0.5
4 0.5 -0.537182 0 bm9p02	3 0.2	13 1 iop16	3 0.2	3 0.5
2 -11.25 0	9 0	19 0.2 1.44 s3p16	9 0	3 0.5
3 0.2	3 0.4	3 0.25	3 0.4	19 0.05 17.923 sif4
5 0.2 -1.2 100 qx9p02	5 0.2 7.2323 100 q5p06	4 1.4 0 0 kp16	5 0.2 7.02619 100 q5p28	3 0.1
3 0.2	3 0.2	3 1	3 0.2	13 1 ioptar
3 1.4	5 0.2 -0.6458 100 q6p06	3 0.5	5 0.2 -9.1697 100 q6p28	3 2 firepnt
3 1	3 0.25	3 0.5	3 0.25	13 1 iorfp
5 0.2 -1.0598 100 q5p02	5 0.2 -7.3263 100 q7p06	3 0.5	5 0.2 4.991 100 q7p28	21 8 2 200
3 0.2	3 0.2	4 0.5 0 0 bsep16	3 0.2	21 8 5 500
5 0.2 0.4111 100 q6p02	5 0.2 4.1652 100 q8p06	3 0.5	5 0.2 -1.7786 100 q8p28	
3 0.25	20 -90 rot03	3 0.5	13 1 iop29	
5 0.2 3.1038 100 q7p02	13 1 iop7	19 0.2 0 s4p16	3 1	
3 0.2	3 1	13 1 iop21	3 1	
5 0.2 -2.2552 100 q8p02	3 1	3 2.7638 lvx03	3 1	
3 1 ixx	19 0.2 1 s1i04	13 1 iop22	19 0.2 1 s1i15	

Table 52
Transport data file: data.L5

DiagX Line 5				
0				
15 11 MeV/C 0.001				
13 2.1	19 0.25 1.34 s3p04	4 0.5 0.513307 0 bsep08	3 3.7756 lvz05	5 0.2 -7.18125 100 q1p36
16 3 1	3 0.25	2 10.525 0	13 1 iop34	3 0.2
16 6 -0.351	4 1.4 0 0 kqs	3 0.2	5 0.2 -3.2 100 q1p34	5 0.2 11.5795 100 q2p36
16 16 0.08	3 2.5	9 3	3 0.2	3 0.2
16 29 -1	16 16 0.19	5 0.2 -6.3329 100 qf9p08	5 0.2 4.2 100 q2p34	5 0.2 -6.9325 100 q3p36
24 0 9 9 0 0 0	5 0.51 -4.5 100 qseptm	3 0.2	3 0.6	3 0.2
13 12	3 0.25	5 0.2 7.5243 100 qd9p08	5 0.2 3 100 q3p34	5 0.2 3.51721 100 q4p36
24 8 0 0 -0.851 0 0	16 16 0.06	3 0.2	3 0.2	13 1 iop37
1 0.5 6 0.5 6 0 0 20.5044 beam1	5 0.25 6 100 qxh	2 11.25 0	5 0.2 -5.5 100 q4p34	3 1.5
12 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	3 0.8	4 0.5 0.537182 0 bm9p08	3 0.75	19 0.2 2.5 sli19
6 7 8 4	5 0.25 -5 100 qxv	2 11.25 0	9 4	3 1
6 6 12 12	3 0.25	3 0.2	5 0.2 8.5722 100 qd6p34	3 2 lvzx5b
6 7 12.7 19	5 0.25 2.6 100 qxw	9 0	3 0.2	13 1 iop38
19 4.178 1.6009 1708	16 16 0.08	3 0.4	2 -8.4375 0	20 90
3 0.1111	3 0.5 lxx2	5 0.2 5.50625 100 q1p08	4 0.5 -0.402886 0 bm6p34	5 0.2 -3 100 q1p38
6 7 8.5 19	20 90 rol02	3 0.2	2 -8.4375 0	3 0.2
19 0.25 0 ss0	5 0.2 -8 100 q1p06	5 0.2 -8.27972 100 q2p08	3 0.2	5 0.2 4 100 q2p38
20 -10 rol01	3 0.2	3 0.2	5 0.2 -9.254 100 qf6p34	3 0.6
3 0.2	5 0.2 4 100 q2p06	5 0.2 4.82671 100 q3p08	3 0.2	5 0.2 3.3 100 q3p38
5 0.2 10 100 q1p02	3 0.6	3 0.2	9 0	3 0.2
3 0.2	5 0.2 6 100 q3p06	5 0.2 0.06473 100 q4p08	3 0.4	5 0.2 -5.5 100 q4p38
5 0.2 -10 100 q2p02	3 0.2	13 1 iop9	5 0.2 9.774 100 q5p34	3 0.4
3 0.2	5 0.2 -8.5 100 q4p06	3 3.5	3 0.2	9 4
3 0.2	3 0.4	19 0.2 0 sli05	5 0.2 -8.1991 100 q6p34	5 0.2 8.28944 100 qdip38
9 3	9 4	3 3.5	3 0.25	3 0.2
5 0.2 8.17775 100 qf9p02	5 0.2 8.28944 100 qdip06	19 0.2 0 s2i05	5 0.2 -3.2259 100 q7p34	4 0.5 0.059688 0 bmlp38
3 0.2	3 0.2	3 3.5	3 0.2	3 0.2
2 -11.25 0	4 0.5 -0.059687 0 bmlp06	19 0.2 0 s3i05	5 0.2 8.0349 100 q8p34	5 0.2 -8.2406 100 qf1p38
4 0.5 -0.537182 0 bm9p02	3 0.2	3 2.35 lvz01	13 1 iop35	3 0.2
2 -11.25 0	5 0.2 -8.2406 100 qf1p06	13 1 iop10	3 1	9 0
3 0.2	3 0.2	19 0.2 1.7 s3p10	3 1	3 0.4
5 0.2 -7.71653 100 qd9p02	9 0	3 0.25	19 0.2 0.6 sti18	5 0.2 -1.6025 100 q5p38
3 0.2	3 0.4	4 1.4 0 0 kp10	3 0.8	3 0.2
9 0	5 0.2 7.2323 100 q5p06	3 1	3 2.055 lvzx5	5 0.2 0.1406 100 q6p38
5 0.2 8.17775 100 qf9p02	3 0.2	3 0.5	13 1 iop36	3 0.25
3 0.2	5 0.2 -0.6458 100 q6p06	3 0.5	19 0.2 1.98 s3p36	5 0.2 6.2421 100 q7p38
2 -11.25 0	3 0.25	3 0.5	3 0.25	3 0.2
4 0.5 -0.537182 0 bm9p02	5 0.2 -7.3263 100 q7p06	4 0.5 0 0 bsep10	4 1.4 -0.008527 0 kp36	5 0.2 -5.5352 100 q8p38
2 -11.25 0	3 0.2	3 1	3 2.5	13 1 iop39
3 0.2	5 0.2 4.1652 100 q8p06	19 0.2 2 s4p10	2 -10.525 0	3 1.366 lvz05
5 0.2 -1.2 100 qx9p02	20 -90 rol03	13 1 iop33	4 0.5 -0.513307 0 bsep36	19 0.2 2 sti20
3 0.2	3 2	3 1	2 -10.525 0	3 4
3 1.4	19 0.2 1 sli04	3 1	3 0.2	19 0.05 18.2217 siff5
3 1	3 2	3 1	9 3	3 0.1
5 0.2 -1.0598 100 q5p02	19 0.2 0 s2i04	19 0.2 1 sti17	5 0.2 -6.3329 100 qf9p36	13 1 ioptar
3 0.2	3 2	3 1	3 0.2	3 2 firepnt
5 0.2 0.4111 100 q6p02	19 0.2 0 s3i04	3 1	5 0.2 7.5243 100 qd9p36	13 1 iofp
3 0.25	3 2.6002	3 1	3 0.2	21 8 2 200
5 0.2 3.1038 100 q7p02	13 1 iop8	19 0.2 0 s2i17	2 -11.25 0	21 8 5 500
3 0.2	19 0.2 1.6 s3p08	3 1	4 0.5 -0.537182 0 bm9p36	
5 0.2 -2.3582 100 q8p02	3 0.25	3 1	2 -11.25 0	
3 1 lxx	4 1.4 0.008527 0 kb08	3 1	3 0.2	
13 1	3 2.5	19 0.2 0 s3i17	9 0	
19 0.25 1.34 s3p04	2 10.525 0	3 1	3 0.4	

Table 53
Transport data file: data.L6

DiagX Line 6				
0				
15 11 MeV/C 0.001				
13 2.1	5 0.25 -5 100 qxv	3 0.2	3 1	2 -10.525 0
16 3 1	3 0.25	5 0.2 0.06473 100 q4p08	19 0.2 2.4 s4p36	3 0.2
16 6 -0.851	5 0.25 2.6 100 qxw	3 3.5	3 3	9 3
16 16 0.08	16 16 0.08	19 0.2 0 s1i05	19 0.2 1.2 s1i21	5 0.2 -6.3329 100 qf9p44
16 29 -1	3 0.5 lxx	3 3.5	3 3.2	3 0.2
24 0 9 9 0 0 0	20 90	19 0.2 0 s2i05	19 0.2 1.2 s2i21	5 0.2 7.5243 100 qd9p44
13 12	5 0.2 -8 100 q1p06	3 3.5	3 3.2	3 0.2
24 8 0 0 -0.851 0 0	3 0.2	19 0.2 0 s3i05	19 0.2 1.2 s3i21	2 -11.25 0
1 0.5 6 0.5 6 0 0 20.5044 beam1	5 0.2 4 100 q2p06	3 2.35 lvz01	3 3.2	4 0.5 -0.537182 0 bm9p44
12 0 0 0 0 0 0 0 0 0 0 0 0 0	3 0.6	13 1 iop10	19 0.2 1.2 s4i21	2 -11.25 0
6 7 8 4	5 0.2 6 100 q3p06	19 0.2 1.7 s3p10	3 3.2	3 0.2
6 6 12 12	3 0.2	3 0.25	19 0.2 1.2 s5i21	9 0
6 7 12.7 19	5 0.2 -8.5 100 q4p06	4 1.4 0 0 kp10	3 3.2	3 0.4
19 4.178 1.6008 J708	3 0.4	3 2.5	19 0.2 1.1 s6i21	5 0.2 -4.3479 100 q1p44
3 0.1111	9 4	4 0.5 0 0 bsep10	3 1	3 0.2
6 7 8.5 19	5 0.2 8.28944 100 qd1p06	3 1	3 1.6 lvzx6	5 0.2 7.07355 100 q2p44
19 0.25 0 ss0	3 0.2	19 0.2 2 s4p10	13 1 iop42	3 0.2
20 -10	4 0.5 -0.059687 0 bm1p06	3 3	5 0.2 -4 100 q1p42	5 0.2 -6.4049 100 q3p44
3 0.2	3 0.2	19 0.2 1 s1i17	3 0.2	3 0.2
5 0.2 10 100 q1p02	5 0.2 -8.2406 100 qf1p06	3 3	5 0.2 5 100 q2p42	5 0.2 3.9672 100 q4p44
3 0.2	3 0.2	19 0.2 0 s2i17	3 0.6	13 1 iop45
5 0.2 -10 100 q2p02	9 0	3 3	5 0.2 4.5 100 q3p42	3 1.5
3 0.4	3 0.4	19 0.2 0 s3i17	3 0.2	3 1.5
9 3	5 0.2 7.2323 100 q5p06	3 1	5 0.2 -9 100 q4p42	19 0.2 1.7 s1i23
5 0.2 8.17775 100 qf9p02	3 0.2	3 3.7756 lvz05	3 0.4	3 1
3 0.2	5 0.2 -0.6458 100 q6p06	13 1 iop34	9 3	3 3.119173 lvza6
2 -11.25 0	3 0.25	5 0.2 -3.2 100 q1p34	5 0.2 8.58472 100 qd9p42	13 1
4 0.5 -0.537182 0 bm9p02	5 0.2 -7.3263 100 q7p06	3 0.2	3 0.2	20 14 rol45
2 -11.25 0	3 0.2	5 0.2 4.2 100 q2p34	2 -11.25 0	5 0.2 -3 100 q1p46
3 0.2	5 0.2 4.1652 100 q8p06	3 0.6	4 0.5 -0.537182 0 bm9p42	3 0.2
5 0.2 -7.71653 100 qd9p02	20 -90	5 0.2 3 100 q3p34	2 -11.25 0	5 0.2 4 100 q2p46
3 0.2	3 2	3 0.2	3 0.2	3 0.6
9 0	19 0.2 1 s1i04	5 0.2 -5.5 100 q4p34	5 0.2 -9.23702 100 qf9p42	5 0.2 3.3 100 q3p46
5 0.2 8.17775 100 qf9p02	3 2	3 0.75	3 0.2	3 0.2
3 0.2	19 0.2 0 s2i04	9 4	9 0	5 0.2 -5.5 100 q4p46
2 -11.25 0	3 2	5 0.2 8.5722 100 qd6p34	5 0.2 8.58472 100 qd9p42	3 0.75
4 0.5 -0.537182 0 bm9p02	19 0.2 0 s3i04	3 0.2	3 0.2	9 4
2 -11.25 0	3 2.6002	2 -8.4375 0	2 -11.25 0	5 0.2 8.4326 100 qd4p46
3 0.2	13 1 iop8	4 0.5 -0.402886 0 bm6p34	4 0.5 -0.537182 0 bm9p42	3 0.2
5 0.2 -1.2 100 qx9p02	19 0.2 1.6 s3p08	2 -8.4375 0	2 -11.25 0	4 0.5 0.2738 0 bm4p46
3 0.2	3 0.25	3 0.2	3 0.2	3 0.2
3 1.4	4 1.4 0.008527 0 kp08	5 0.2 -9.254 100 qf6p34	5 0.2 -6.6 100 qx9p42	5 0.2 -9.2843 100 qf4p46
3 1	3 2.5	3 0.2	3 0.2	3 0.2
5 0.2 -1.0598 100 q5p02	2 10.525 0	9 0	3 0.4	9 0
3 0.2	4 0.5 0.513307 0 hsep08	3 0.4	5 0.2 7.31557 100 q5p42	5 0.2 3.296 100 q5p46
5 0.2 0.4111 100 q6p02	2 10.525 0	5 0.2 9.774 100 q5p34	3 0.2	3 0.2
3 0.25	3 0.2	3 0.2	5 0.2 -1.4967 100 q6p42	5 0.2 10.16285 100 q6p46
5 0.2 3.1038 100 q7p02	9 3	5 0.2 -8.1991 100 q6p34	3 0.25	3 0.25
3 0.2	5 0.2 -6.3329 100 qf9p08	3 0.25	5 0.2 -5.7555 100 q7p42	5 0.2 -11.92415 100 q7p46
5 0.2 -2.3582 100 q8p02	3 0.2	5 0.2 -3.2259 100 q7p34	3 0.2	3 0.2
3 1 lxx	5 0.2 7.5243 100 qd9p08	3 0.2	5 0.2 1.0977 100 q8p42	5 0.2 8.09846 100 q8p46
13 1 iop4	3 0.2	5 0.2 8.0349 100 q8p34	13 1 iop43	13 1 iop47
19 0.25 1.34 s3p04	2 11.25 0	13 1 iop35	3 1.5	3 0.4
3 0.25	4 0.5 0.537182 0 bm9p08	3 2	3 1.5	3 1.5
4 1.4 0 0 kqs	2 11.25 0	19 0.2 0.6 s1i18	19 0.2 0.8 s1i22	19 0.2 1.5 s1i24
3 2.5	3 0.2	3 0.8	3 2.22535 lvzx66	3 3.709 lvx06
16 16 0.19	9 0	3 2.055 lvzx5	13 1 iop44	19 0.05 15.0034 s1i6
5 0.51 -4.5 100 qseptom	3 0.4	13 1 iop36	19 0.2 1.9 s2p44	3 0.1
3 0.25	5 0.2 5.50625 100 q1p08	19 0.2 1.98 s3p36	3 0.25	13 1 iopiar
16 16 0.06	3 0.2	3 0.25	4 1.4 -0.008527 0 kp44	3 2 firepnt
5 0.25 6 100 qxh	5 0.2 -8.27972 100 q2p08	4 1.4 0 0 kp36	3 2.5	13 1 iopf
3 0.8	3 0.2	3 2.5	2 -10.525 0	21 8 2 200
5 0.25 -8 100 qxs	5 0.2 4.32671 100 q3p08	4 0.5 0 0 bsep36	4 0.5 -0.513307 0 hsep44	21 8 5 500

Table 54
Transport data file: data.L7

Diagn Line 7				
0				
15 11 MeV/C 0.001				
13 2.1	16 16 0.08	3 3.5	19 0.2 1.2 s4i21	5 0.2 -6.3329 100 qf9p50
16 3 1	3 0.5 lxx	19 0.2 0 s3i05	3 3.2	3 0.2
16 6 -0.851	20 90	3 2.35 lvz01	19 0.2 1.2 s5i21	5 0.2 7.5243 100 qd9p50
16 16 0.08	5 0.2 -8 100 q1p06	13 1 iop10	3 3.2	3 0.2
16 29 -1	3 0.2	19 0.2 1.7 s3p10	19 0.2 1.1 s6i21	2 -11.25 0
24 0 9 9 0 0 0	5 0.2 4 100 q2p06	3 0.25	3 1	4 0.5 -0.5371 0 bm9p50
13 12	3 0.6	4 1.4 0 0 kp10	3 1.6 lvzx6	2 -11.25 0
24 8 0 0 -0.851 0 0	5 0.2 6 100 q3p06	3 2.5	13 1 iop42	3 0.2
1 0.5 6 0.5 6 0 0 20.5044 beam1	3 0.2	4 0.5 0 0 bsep10	5 0.2 -4 100 q1p42	9 0
12 0 0 0 0 0 0 0 0 0 0 0 0 0 0	5 0.2 -3.5 100 q4p06	3 1	3 0.2	3 0.4
6 7 8 4	3 0.4	19 0.2 2 s4p10	5 0.2 5 100 q2p42	5 0.2 -2.6901 100 q1p50
6 6 12 12	9 4	3 3	3 0.6	3 0.2
6 7 12.7 19	5 0.2 3.28944 100 qd1p06	19 0.2 1 s1i17	5 0.2 4.5 100 q3p42	5 0.2 -2.6827 100 q2p50
19 4.178 1.6009 J701	3 0.2	3 3	3 0.2	3 0.2
3 0.1111	4 0.5 -0.059687 0 bmlp06	19 0.2 0 s2i17	5 0.2 -9 100 q4p42	5 0.2 6.3278 100 q3p50
6 7 8.5 19	3 0.2	3 0.2	3 0.4	3 0.2
19 0.25 0 ss0	5 0.2 -8.2406 100 qf1p06	19 0.2 0 s3i17	9 3	5 0.2 -2.2997 100 q4p50
20 -10	3 0.2	3 1	5 0.2 8.58472 100 qd9p42	13 1 iop51
3 0.2	9 0	3 3.7756 lvz05	3 0.2	3 1.5
5 0.2 10 100 q1p02	3 0.4	13 1 iop34	2 -11.25 0	3 1.3
3 0.2	5 0.2 7.2323 100 q5p06	5 0.2 -3.2 100 q1p34	4 0.5 -0.537182 0 bm9p42	19 0.2 1.6 s1i26
5 0.2 -10 100 q2p02	3 0.2	3 0.2	2 -11.25 0	3 1.165555 lvz07
3 0.4	5 0.2 -0.6458 100 q6p06	5 0.2 4.2 100 q2p34	3 0.2	13 1 iop52
9 3	3 0.25	3 0.6	5 0.2 -9.23702 100 qf9p42	20 90
5 0.2 8.17775 100 qf9p02	5 0.2 -7.3263 100 q7p06	5 0.2 3 100 q3p34	3 0.2	5 0.2 -3 100 q1p52
3 0.2	3 0.2	3 0.2	9 0	3 0.2
2 -11.25 0	5 0.2 4.1652 100 q8p06	5 0.2 -5.5 100 q4p34	5 0.2 8.58472 100 qd9p42	5 0.2 4 100 q2p52
4 0.5 -0.537182 0 bm9p02	20 -90	3 0.75	3 0.2	3 0.6
2 -11.25 0	3 2	9 4	2 -11.25 0	5 0.2 3.3 100 q3p52
3 0.2	19 0.2 1 s1i04	5 0.2 8.5722 100 qd6p34	4 0.5 -0.537182 0 bm9p42	3 0.2
5 0.2 -7.71653 100 qd9p02	3 2	3 0.2	2 -11.25 0	5 0.2 -5.5 100 q4p52
3 0.2	19 0.2 0 s2i04	2 -8.4375 0	3 0.2	3 0.4
9 0	3 2	4 0.5 -0.402886 0 bmlp34	5 0.2 -6.6 100 qx9p42	9 4
5 0.2 8.17775 100 qf9p02	19 0.2 0 s3i04	2 -8.4375 0	3 0.2	5 0.2 3.28944 100 qd1p52
3 0.2	3 2.6002	3 0.2	3 0.4	3 0.2
2 -11.25 0	13 1 iop8	5 0.2 -9.254 100 qf6p34	5 0.2 7.31557 100 q5p42	4 0.5 0.059687 0 bmlp52
4 0.5 -0.537182 0 bm9p02	19 0.2 1.6 s3p08	3 0.2	3 0.2	5 0.2 -8.2406 100 qf1p52
2 -11.25 0	3 0.25	9 0	5 0.2 -1.4967 100 q6p42	3 0.2
3 0.2	4 1.4 0.008527 0 kp08	3 0.4	3 0.25	9 0
5 0.2 -1.2 100 qx9p02	3 2.5	5 0.2 9.774 100 q5p34	5 0.2 -5.7555 100 q7p42	13 1
3 0.2	2 10.525 0	3 0.2	3 0.2	3 0.4
3 1.4	4 0.5 0.513307 0 bsep08	5 0.2 -8.1991 100 q6p34	5 0.2 1.0977 100 q8p42	5 0.2 1.67227 100 q5p52
3 1	2 10.525 0	3 0.25	13 1 iop43	3 0.2
5 0.2 -1.0598 100 q5p02	3 0.2	5 0.2 -3.2259 100 q7p34	3 1.5	5 0.2 4.95075 100 q6p52
3 0.2	9 3	3 0.2	3 1.5	3 0.25
5 0.2 0.4111 100 q6p02	5 0.2 -6.3329 100 qf9p08	5 0.2 8.0349 100 q8p34	19 0.2 0.8 s1i22	5 0.2 -5.6906 100 q7p52
3 0.25	3 0.2	13 1 iop35	3 2.23535 lvzx6b	3 0.2
5 0.2 3.1038 100 q7p02	5 0.2 7.5243 100 qd9p08	3 2	13 1 iop44	5 0.2 1.5026 100 q8p52
3 0.2	3 0.2	19 0.2 0.6 s1i18	19 0.2 1.9 s2p44	20 -90
5 0.2 -2.3582 100 q8p02	2 11.25 0	3 0.8	3 0.25	13 1 iop53
3 1 lxx	4 0.5 0.537182 0 bm9p08	3 2.055 lvzx5	4 1.4 0 0 kp44	3 1.37 lvx7
13 1 iop4	2 11.25 0	13 1 iop36	3 2.5	19 0.2 1.9 s1i27
19 0.25 1.34 s3p04	3 0.2	19 0.2 1.98 s3p26	4 0.5 0 0 bsep44	3 4
3 0.25	9 0	3 0.25	3 1	19 0.05 18.2 s1i7
4 1.4 0 0 kqs	3 0.4	4 1.4 0 0 kp36	19 0.2 1 s4p44	3 0.1
3 2.5	5 0.2 5.50625 100 q1p08	3 2.5	3 2.772158 lvx07	13 1 iop49
16 16 0.19	3 0.2	4 0.5 0 0 bsep36	13 1 iop50	3 2 s1repu
5 0.51 -4.5 100 qseptm	5 0.2 -8.27972 100 q2p08	3 1	19 0.2 2 s3p50	13 1 iop6
3 0.25	3 0.2	19 0.2 2.4 s4p36	3 0.25	21 8 2 200
16 16 0.06	5 0.2 4.82671 100 q3p08	3 3	4 1.4 -0.008527 0 kp50	21 8 5 500
5 0.25 6 100 qxh	3 0.2	19 0.2 1.2 s1i21	3 2.5	
3 0.8	5 0.2 0.06473 100 q4p08	3 3.2	2 -10.525 0	
5 0.25 -5 100 qxx	3 3.5	19 0.2 1.2 s2i21	4 0.5 -0.513307 0 bsep50	
3 0.25	19 0.2 0 s1i05	3 3.2	2 -10.525 0	
5 0.25 2.6 100 qxx	3 3.5	19 0.2 1.2 s3i21	3 0.2	
16 16 0.08	19 0.2 0 s2i05	3 3.2	9 3	

Table 55
Transport data file: data.L8

Diagn Line 3				
0				
15 11 MeV/C 0.001				
13 2.1	20 90	3 2.35 lvz01	19 0.2 1.1 s6i21	3 0.2
16 3 1	5 0.2 -8 100 q1p06	13 1 iop10	3 2.6 lvzx6	5 0.2 -2 100 q4p56
16 6 -0.851	3 0.2	19 0.2 1.7 s3p10	13 1 iop42	3 0.4
16 16 0.08	5 0.2 + 100 q2p06	3 0.25	5 0.2 -4 100 q1p42	9 4
16 29 -1	3 0.6	4 1.4 0 0 kp10	3 0.2	5 0.2 8.58472 100 qd9p56
24 0 9 9 0 0 0	5 0.2 6 100 q3p06	3 2.5	5 0.2 5 100 q2p42	3 0.2
13 12	3 0.2	4 0.5 0 0 bsep10	3 0.6	2 -11.25 0
24 8 0 0 -0.851 0 0	5 0.2 -8.5 100 q4p06	3 1	5 0.2 4.5 100 q3p42	4 0.5 -0.537182 0 bm9p56
1 0.5 6 0.5 6 0 0 20.5044 beam1	3 0.4	19 0.2 2 s4p10	3 0.2	2 -11.25 0
12 0 0 0 0 0 0 0 0 0 0 0 0 0	9 4	3 3	5 0.2 -9 100 q4p42	3 0.2
6 7 8 4	5 0.2 8.28944 100 qd1p06	19 0.2 1 s1i17	3 0.4	5 0.2 -9.23702 100 qf9p56
6 7 12.7 19	3 0.2	3 3	9 3	3 0.2
19 4.178 1.6009 J701	4 0.5 -0.059687 0 bmlp06	19 0.2 0 s2i17	5 0.2 8.58472 100 qd9p42	9 0
13 1 iop1	3 0.2	3 3	3 0.2	3 0.4
3 0.1111	5 0.2 -8.2406 100 qf1p06	19 0.2 0 s3i17	2 -11.25 0	5 0.2 7.5942 100 q5p56
6 7 8.5 19	3 0.2	3 4.7756 lvz05	4 0.5 -0.537182 0 bm9p42	3 0.2
19 0.25 0 ss0	9 0	13 1 iop34	2 -11.25 0	5 0.2 -10.0587 100 q6p56
20 -10	3 0.4	5 0.2 -3.2 100 q1p34	3 0.2	3 0.25
3 0.2	5 0.2 7.2323 100 q5p06	3 0.2	5 0.2 -9.23702 100 qf9p42	5 0.2 3.6072 100 q7p56
5 0.2 10 100 q1p02	3 0.2	5 0.2 4.2 100 q2p34	3 0.2	3 0.2
3 0.2	5 0.2 -0.6458 100 q6p06	3 0.6	9 0	5 0.2 -1.9055 100 q8p56
5 0.2 -10 100 q2p02	3 0.25	5 0.2 3 100 q3p34	5 0.2 8.58472 100 qd9p42	13 1 iop57
3 0.4	5 0.2 -7.3263 100 q7p06	3 0.2	3 0.2	3 2.9
9 3	3 0.2	5 0.2 -5.5 100 q4p34	2 -11.25 0	19 0.2 1.4 s1i29
5 0.2 8.17775 100 qf9p02	5 0.2 4.1652 100 q8p06	3 0.75	4 0.5 -0.537182 0 bm9p42	3 1.4
3 0.2	20 90	9 4	2 -11.25 0	3 2.427344 lvx08
2 -11.25 0	3 2	5 0.2 8.5722 100 qd6p34	3 0.2	13 1 iop58
4 0.5 -0.537182 0 bm9p02	19 0.2 1 s1i04	3 0.2	5 0.2 -6.6 100 qx9p42	20 -14.00238 rot45
2 -11.25 0	3 2	2 -8.4375 0	3 0.2	5 0.2 -3.4 100 q1p58
3 0.2	19 0.2 0 s2i04	4 0.5 -0.402886 0 bm6p34	3 0.4	3 0.2
5 0.2 -7.71653 100 qd9p02	3 2	2 -8.4375 0	5 0.2 7.21557 100 q5p42	5 0.2 4 100 q2p58
3 0.2	19 0.2 0 s3i04	3 0.2	3 0.2	3 0.6
9 0	3 2.60002	5 0.2 -9.254 100 qf6p34	5 0.2 -1.4967 100 q6p42	5 0.2 3.3 100 q3p58
5 0.2 8.17775 100 qf9p02	13 1 iop8	3 0.2	3 0.25	3 0.2
3 0.2	19 0.2 1.6 s3p08	9 0	5 0.2 -5.7555 100 q7p42	5 0.2 -5.5 100 q4p58
2 -11.25 0	3 0.25	3 0.4	3 0.2	3 0.75
4 0.5 -0.537182 0 bm9p02	4 1.4 0.008527 0 kp08	5 0.2 9.774 100 q5p34	5 0.2 1.0977 100 q8p42	9 4
2 -11.25 0	3 2.5	3 0.2	13 1 iop43	5 0.2 8.4326 100 qd4p58
3 0.2	2 10.525 0	5 0.2 -8.1991 100 q6p34	3 3	3 0.2
5 0.2 -1.2 100 qx9p02	4 0.5 0.513307 0 bsep08	3 0.25	19 0.2 0.8 s1i22	4 0.5 -0.273727 0 bm4p58
3 0.2	2 10.525 0	5 0.2 -3.2259 100 q7p34	3 2.23525 lvzx6b	3 0.2
3 2.4	3 0.2	3 0.2	13 1 iop44	5 0.2 -9.2843 100 qf4p58
5 0.2 -1.0598 100 q5p02	9 3	5 0.2 8.0349 100 q8p34	19 0.2 1.9 s3p44	3 0.2
3 0.2	5 0.2 -6.3329 100 qf9p08	13 1 iop35	3 0.25	9 0
5 0.2 0.4111 100 q6p02	3 0.2	3 2	4 1.4 0 0 kp44	3 0.4
3 0.25	5 0.2 7.5243 100 qd9p08	19 0.2 0.6	3 2.5	5 0.2 8.19128 100 q5p58
5 0.2 3.1038 100 q7p02	3 0.2	3 2.855 lvzx5	4 0.5 0 0 bsep44	3 0.2
3 0.2	2 11.25 0	13 1 iop36	3 1	5 0.2 -9.7975 100 q6p58
5 0.2 -2.3582 100 q8p02	4 0.5 0.537182 0 bm9p08	19 0.2 1.98 s3p26	19 0.2 1 s4p44	3 0.25
3 1 lxx	2 11.25 0	3 0.25	3 2.772158 lvx07	5 0.2 2.1961 100 q7p58
19 0.25 1.34 s3p04	3 0.2	4 1.4 0 0 kp36	13 1 iop50	3 0.2
3 0.25	9 0	3 2.5	19 0.2 2 s3p50	5 0.2 1.1678 100 q8p58
4 1.4 0 0 kqs	3 0.4	4 0.5 0 0 bsep36	3 0.25	13 1 iop59
3 2.5	5 0.2 5.50625 100 q1p08	3 1	4 1.4 0 0 kp50	3 1.21 lvx08
16 16 0.19	3 0.2	19 0.2 2.4 s4p36	3 2.5	19 0.2 1.3 s1i30
5 0.51 -4.5 100 qsep	5 0.2 -8.27972 100 q2p08	3 3	4 0.5 0 0 bsep50	3 2
3 0.25	3 0.2	19 0.2 1.2 s1i21	3 3	3 2
16 16 0.06	5 0.2 4.82671 100 q3p08	3 3.2	19 0.2 1.9 s1i28	19 0.05 18.16327 s1i8
5 0.25 6 100 qx8	3 0.2	19 0.2 1.2 s2i21	3 1	3 0.1
3 0.8	5 0.2 0.06473 100 q4p08	3 3.2	3 1.528859 lvz08	13 1 iop48
5 0.25 -5 100 qxv	3 3.5	19 0.2 1.2 s3i21	13 1 iop56	3 2 firepnt
3 0.25	19 0.2 0 s1i05	3 3.2	5 0.2 4 100 q1p56	13 1 iop
5 0.25 2.6 100 qxw	3 3.5	19 0.2 1.2 s4i21	3 0.2	21 5 2 200
16 16 0.08	19 0.2 0 s2i05	3 3.2	5 0.2 -3 100 q2p56	21 5 5 500
3 0.5 lxx	3 3.5	19 0.2 1.2 s5i21	3 0.6	
20 90	19 0.2 0 s3i05	3 3.2	5 0.2 -2 100 q3p56	

LIST OF FIGURES

-
- FIGURE 1 The eight beamlines of Diagnostic X starting from the end of the accelerator and converging on the firing point located at global coordinates (35.0, 70.0, -5.90) meters.
- FIGURE 2 Block diagram of lines 1, 2, 3, and 4 showing the start and ending points and the inter-block spacings.
- FIGURE 3 Block diagram of lines 5, 6, 7, and 7 showing the start and ending points and the inter-block spacings.
- FIGURE 4 Three dipole achromatic bend system with quadrupole triplet matching sections. Geometry layout above, beam envelope below. Also shown with the envelope is a 1% off-energy particle.
- FIGURE 5 Dipole Quadrupole Dipole (DQD) achromatic bend system with quadrupole triplet matching sections. Also shown with the envelope is a 1% off-energy trajectory.
- FIGURE 6 Four QDQ sections with phase advance $\pi/2$. Achromatic bend with quadrupole matching sections.
- FIGURE 7 The kicker quadrupole septum block. The kicker kicks sections of the beam into the straight ahead line. The unkicked portions are deflected by the bias dipole of the kicker into the quadrupole septum off axis. That bends the beam into a dipole septum that increases the deflection to 45 degrees. The beam is then deposited in a beam dump.
- FIGURE 8 The kicker quadrupole septum block kicks sections of the beam into the straight ahead line. The beam phase space and image is shown at the exit of the KQS system, IP05. The beam entering the system has a matched radius of 3 cm and is focused to small size by S3 in front of the quadrupole septum.
- FIGURE 9 --
- FIGURE 10 --
- FIGURE 11 10 degree achromatic bend used to set the elevation and pitch angle of the diagnostic x beamlines. A) the geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells. B) The beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .
- FIGURE 12 --
- FIGURE 13 45 degree achromatic bend used to set the yaw and pitch angle of the beamline 2, 4, 6, and 8. A) The geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells. B) the beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .
- FIGURE 14 --

- FIGURE 15 67.5 degree achromatic bend used to set the yaw index for beamlines 5-8 with respect to lines 1-4. A) the geometrix layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells. B) the beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .
- FIGURE 16 --
- FIGURE 17 90 degree achromatic bend based on four fold symmetry of the QDQ $\pi/2$ phase advance system. A) the geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells. B) the beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .
- FIGURE 18 --
- FIGURE 19 90 degree kicker achromatic bend. The kicker and dipole septum form first cell of the 4 cells. A) beam line plot, location 1 starts the block, location 5 ends the block at the exit of the last quadrupole. B) Geometry showing the kicked 90 degree bend and the unkicked straight ahead beamlines.
- FIGURE 20 K90 block showing the unkicked beam trace and geometry layout.
- FIGURE 21 Transverse beam size for the kicked and un-kicked beams showing size and centroid displacements. The septum of the K90 block and vacuum walls of the vessel must be in the space between the two beams.
- FIGURE 22 Achromatic breakout from the accelerator hall showing blocks A90 and KQS. A) The geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells. B) The beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .
- FIGURE 23 --
- FIGURE 24 Timing of beamlines 1 through 4 fired in sequential order. A) division of the 2usec accelerator pulse. B) arrival time profile for burst 1. C) arrival time profile for burst 2 D) arrival time profile for burst 3 E) arrival time profile for burst 4.
- FIGURE 25 Timing of beamlines 5 through 8 fired in sequential order. A) division of the 2usec accelerator pulse. B) arrival time profile for burst 1. C) arrival time profile for burst 2 D) arrival time profile for burst 3 E) arrival time profile for burst 4.
- FIGURE 26 Beamlines 1 through 4 can be switched in any one of 4 arrival time of the four pulses at their respective targets is controlled by that sequence, the length and therefore the transit time of the lines, and the selected pulse length. These 24 sequences are shown on the following four pages, six sequences per page in the order given in table 31 along with the time span for that sequence. The minimum time is for sequence 3 4 2 1.

- FIGURE 27 Beamlines 5 through 8 can be switched in any one of 4 arrival time of the four pulses at their respective targets is controlled by that sequence, the length and therefore the transit time of the lines, and the selected pulse length. These 24 sequences are shown on the following four pages, six sequences per page in the order given in table 32 along with the time span for that sequence. The minimum time is for sequence 8 7 6 5.
- FIGURE 28 Timing beamlines 1 through 4 fired in sequence 3421. A)division of the 2usec accelerator pulse. B)arrival time profile for burst 1. C)arrival time profile for burst 2. D)arrival time profile for burst 3. E)arrival time profile for burst 4.
- FIGURE 29 Timing beamlines 5 through 8 fired in sequence 8765. A)division of the 2usec accelerator pulse. B)arrival time profile for burst 1. C)arrival time profile for burst 2. D)arrival time profile for burst 3. E)arrival time profile for burst 4.
- FIGURE 30 Kicker firing sequences for A)minimum arrival times at the firing point, B) numerically sequential order, and C) sequences giving maximum number of septum transversals.
- FIGURE 31 Beamline 1 geometry plot form the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 32 Beamline 1 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 15. The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.
- FIGURE 33 Beamline 1 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 4, kicker K90p08 follows IO 8, kicker K90p10 follows IO 10. The firing point is located at IO point 15.
- FIGURE 34 Beamline 2 geometry plot form the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 35 Beamline 2 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 11. The beam phase space and spot size at the X-ray converter target located at IO location 10 is also shown. IO 10 is indicated at the top of the envelope plot.
- FIGURE 36 Beamline 2 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x .

Kicker KQS follows IO point 1, kicker K90p08 follows IO 4, kicker K90p10 follows IO 6. The firing point is located at IO point 11.

- FIGURE 37 Beamline 3 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 38 Beamline 3 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 15. The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.
- FIGURE 39 Beamline 3 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 4, kicker K90p08 follows IO 6, kicker K90p10 follows IO 8. The firing point is located at IO point 15.
- FIGURE 40 Beamline 4 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 41 Beamline 4 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 15. The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.
- FIGURE 42 Beamline 4 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 3, kicker K90p08 follows IO 7, kicker K90p10 follows IO 10. The firing point is located at IO point 15.
- FIGURE 43 Beamline 5 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 44 Beamline 5 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 13. The beam phase space and spot size at the X-ray converter target located at IO location 12 is also shown. IO 12 is indicated at the top of the envelope plot.
- FIGURE 45 Beamline 5 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 3, kicker K90p08 follows IO 7, kicker K90p10 follows IO 4. The firing point is located at IO point 15.

- FIGURE 46 Beamline 6 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 47 Beamline 6 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 15. The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.
- FIGURE 48 Beamline 6 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 4, kicker K90p08 follows IO 8, kicker K90p10 follows IO 10. The firing point is located at IO point 15.
- FIGURE 49 Beamline 7 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 50 Beamline 7 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 15. The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.
- FIGURE 51 Beamline 7 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 4, kicker K90p08 follows IO 8, kicker K90p10 follows IO 10. The firing point is located at IO point 15.
- FIGURE 52 Beamline 8 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point for reference. The firing point is located at global coordinates 35.0, 70.0, -5.90 meters from the LLNL origin.
- FIGURE 53 Beamline 8 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round $x=y=5$. The firing point is located at IO point 15. The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.
- FIGURE 54 Beamline 8 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, the maximum of x/y or y/x . Kicker KQS follows IO point 4, kicker K90p08 follows IO 8, kicker K90p10 follows IO 10. The firing point is located at IO point 15.
- FIGURE 55 Four beamlines, 1, 2, 3, and 4 of Diagnostic X starting from end of the accelerator and converging on the firing point.

FIGURE 56 Four beamlines, 5, 6, 7, and 8 of Diagnostic X starting from end of the accelerator and converging on the firing point.

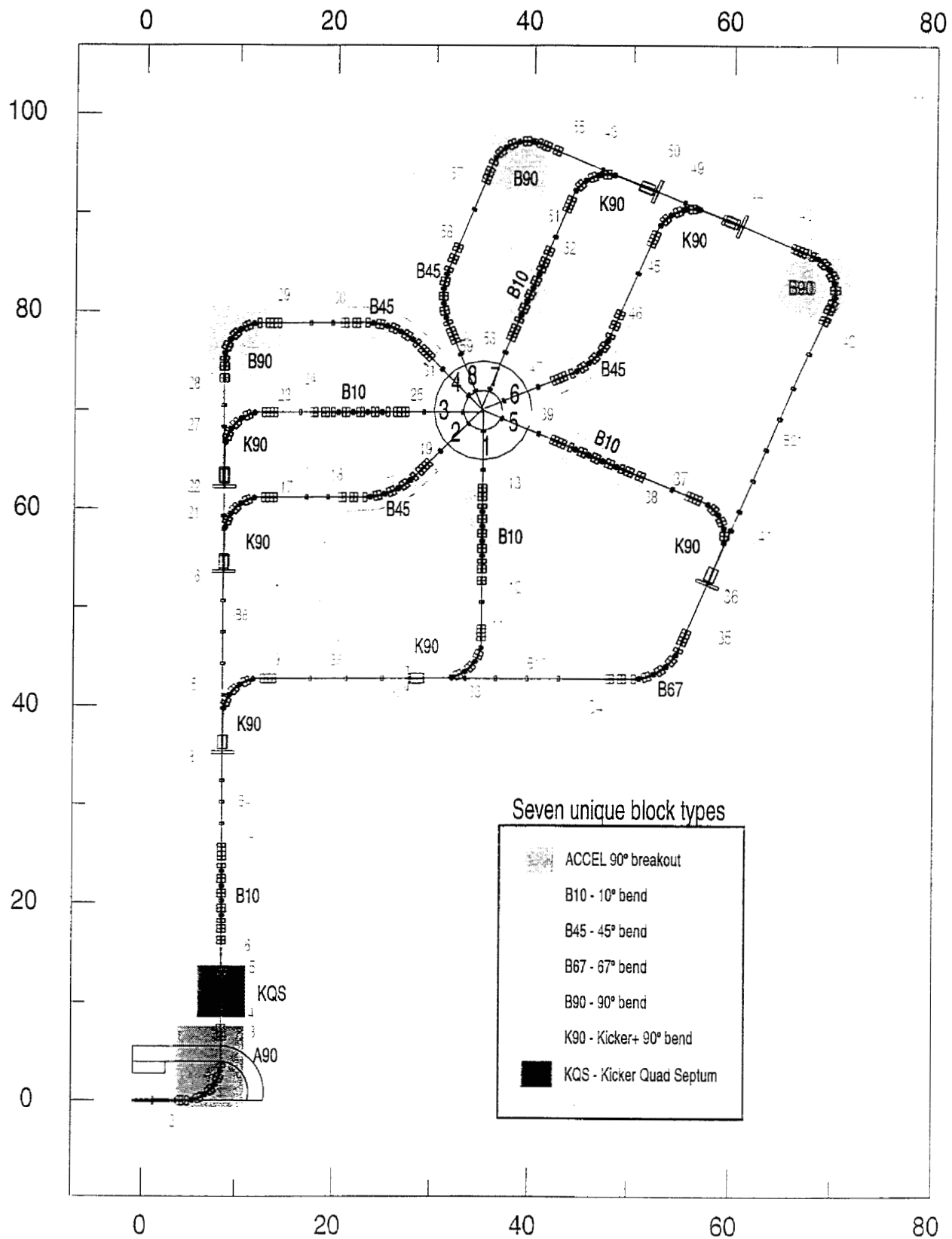


Figure 1. Eight beamlines of Diagnostic X starting from the end of the accelerator and converging on the firing point.

DIAGNOSTIC X

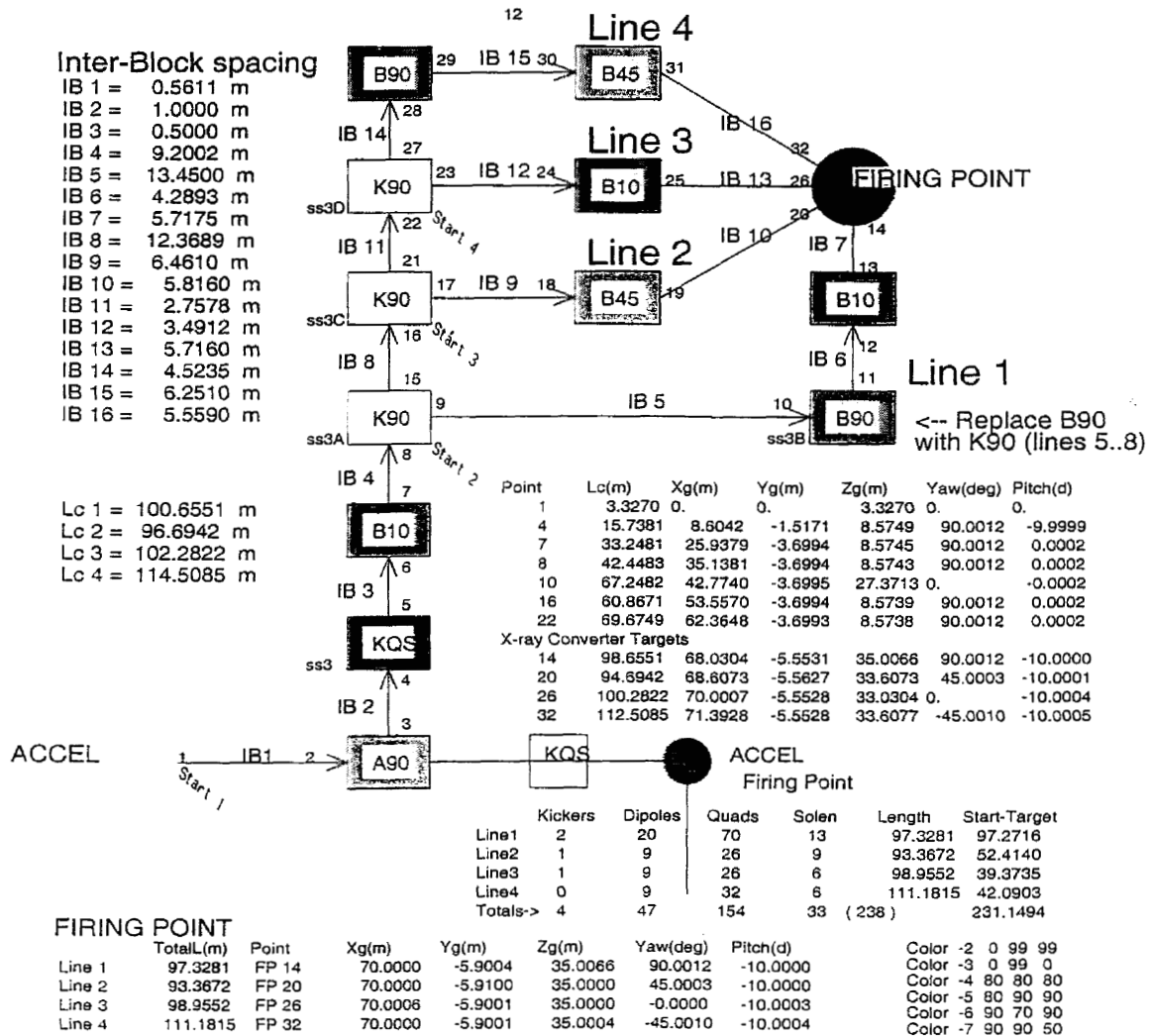
DX124

Beamlines 1-4 of 8

Made from six unique Block types

- 1) ACCEL 90 degree break-out, A90
- 2) 10 degree achromatic bend, B10
- 3) 45 degree achromatic bend, B45
- 4) 90 degree achromatic bend, B90
- 5) Kicker Quadrupole septum, KQS
- 6) Kicker+90d achromatic bend, K90

Line2 B45 roll -14.00189 d, B(kg)=-0.273746
Line4 B45 roll 14.00200 d, B(kg)= 0.27375



DIAGNOSTIC X

DX128

Beamlines 5-8 of 8

Made from seven unique Block types

- 1) ACCEL 90 degree break-out, A90
- 2) 10.0 degree achromatic bend, B10
- 3) 45.0 degree achromatic bend, B45
- 4) 67.5 degree achromatic bend, B67
- 5) 90.0 degree achromatic bend, B90
- 6) Kicker Quad septum dump, KQS
- 7) Kicker+90d achromatic bend, K90

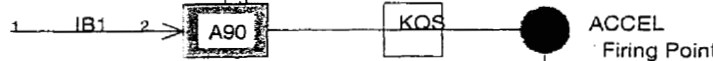
Line6 B45 roll 14.00 d, B(kg)= 0.2738
Line8 B45 roll -14.00238 d, B(kg)=-0.273727

Inter-Block spacing

IB 1 = 0.5611 m
IB 2 = 1.0000 m
IB 3 = 0.5000 m
IB 4 = 9.2002 m
IB 5 = 13.4500 m
IB 17 = 14.3756 m
IB 18 = 5.0550 m
IB 19 = 4.7000 m
IB 20 = 5.7160 m
IB 21 = 23.8000 m
IB 22 = 5.4353 m
IB 23 = 7.3192 m
IB 24 = 5.5590 m
IB 25 = 2.7722 m
IB 26 = 4.1656 m
IB 27 = 5.7200 m
IB 28 = 4.5289 m
IB 29 = 6.9273 m
IB 30 = 5.5600 m

Lc 5 = 136.9449 m
Lc 6 = 184.0928 m
Lc 7 = 189.5724 m
Lc 8 = 201.9031 m

ACCEL



Point	Lc(m)	Xg(m)	Yg(m)	Zg(m)	Yaw(deg)	Pitch(d)
1	3.3270	0.	0.	3.3270	0.	0.
10	67.2483	42.7740	-3.6995	27.3713	0.	-0.0002
36	103.1288	52.3746	-3.6995	57.6100	67.5008	0.0001
44	147.4642	88.7424	-3.6995	60.5808	157.5020	0.0002
50	156.2864	92.1183	-3.6994	52.4301	157.5020	0.0002
X-Ray Converter Targets						
40	134.9449	69.2503	-5.5529	36.8198	157.5020	-10.0001
48	182.0928	70.7537	-5.5528	36.8200	-157.5065	-10.0001
54	187.5724	71.8196	-5.5535	35.7541	-112.5072	-10.0002
60	199.8031	71.8198	-5.5529	34.2464	-67.4998	-10.0000

	Kickers	Dipoles	Quads	Solen	Length	Start-Target
Line5	2	13	42	8	133.6179	81.4145
Line6	1	13	42	10	180.7652	72.7084
Line7	1	9	26	5	186.2448	37.1526
Line8	0	9	32	4	198.4754	39.9686
Totals->	4	44	142	27	(217)	211.2440

FIRING POINT

	TotalL(m)	Point	Xg(m)	Yg(m)	Zg(m)	Yaw(deg)	Pitch(d)	Color
Line 5	133.6179	FP 40	70.0040	-5.9002	35.0000	157.5019	-10.0000	-2 0 99 99
Line 6	180.7652	FP 48	70.0001	-5.9001	35.0003	-157.5060	-10.0000	-3 0 99 0
Line 7	186.2448	FP 54	70.0000	-5.9008	35.0001	-112.5070	-10.0002	-4 80 80 80
Line 8	198.4754	FP 60	70.0001	-5.9002	35.0001	-67.4998	-10.0000	-5 80 90 90
								-6 90 70 90
								-7 90 90 50
								-8 0 0 99

/export/work/acpaul/diag/dx12
data.layout

01/08/00 A.C.Paul
29-Mar-00

Figure 3) Block diagram of lines 5, 6, 7, 8 showing the start and ending points and inter-block spacings.

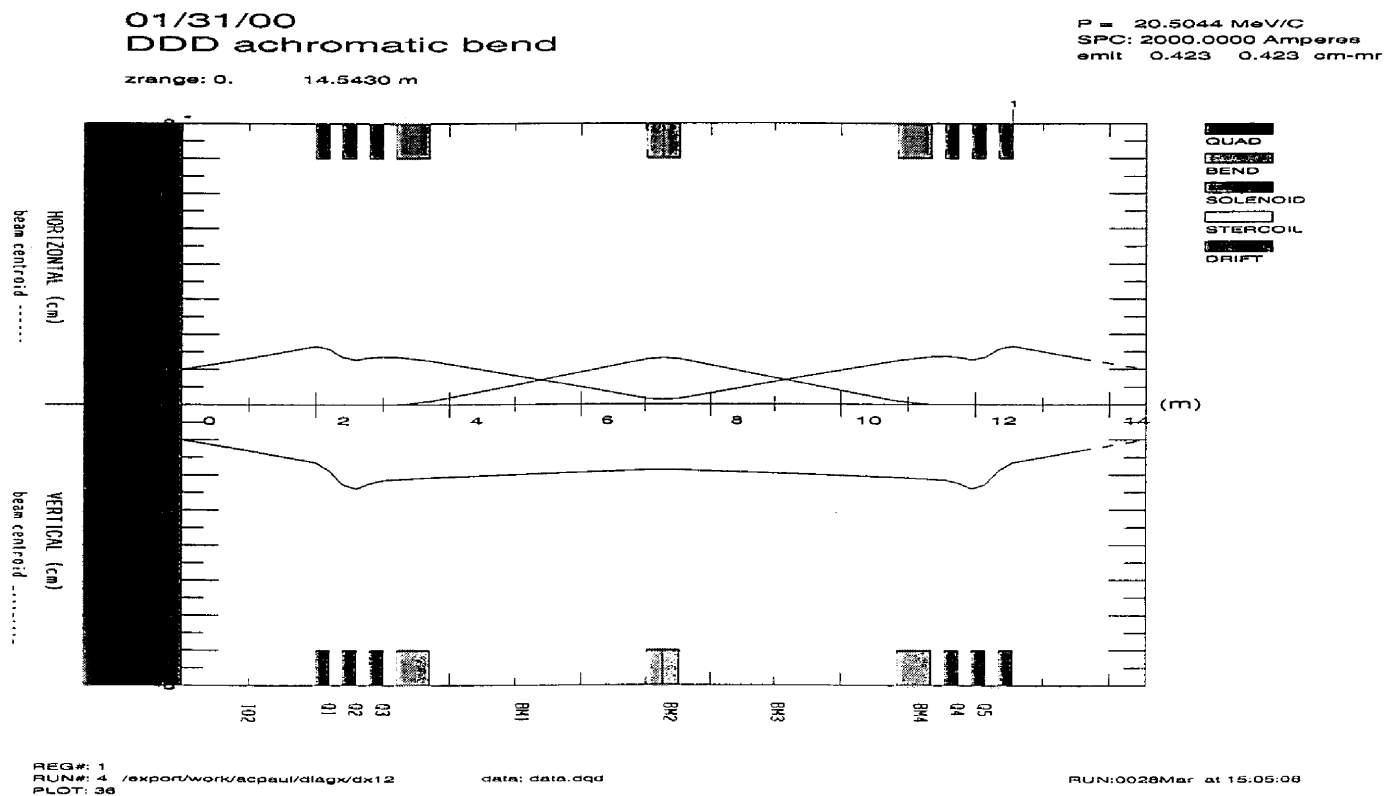
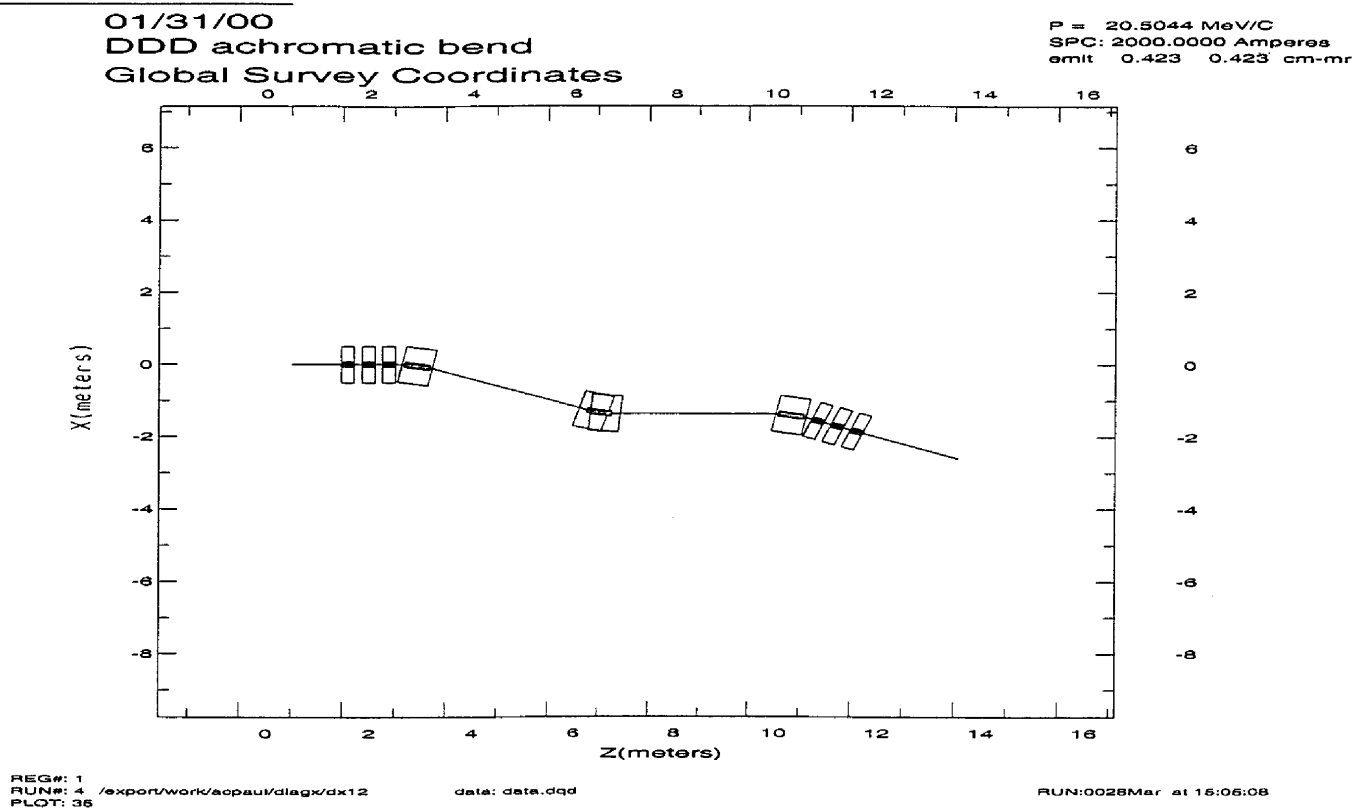


Figure 4). Three Dipole achromatic bend system with quadrupole triplet matching sections.

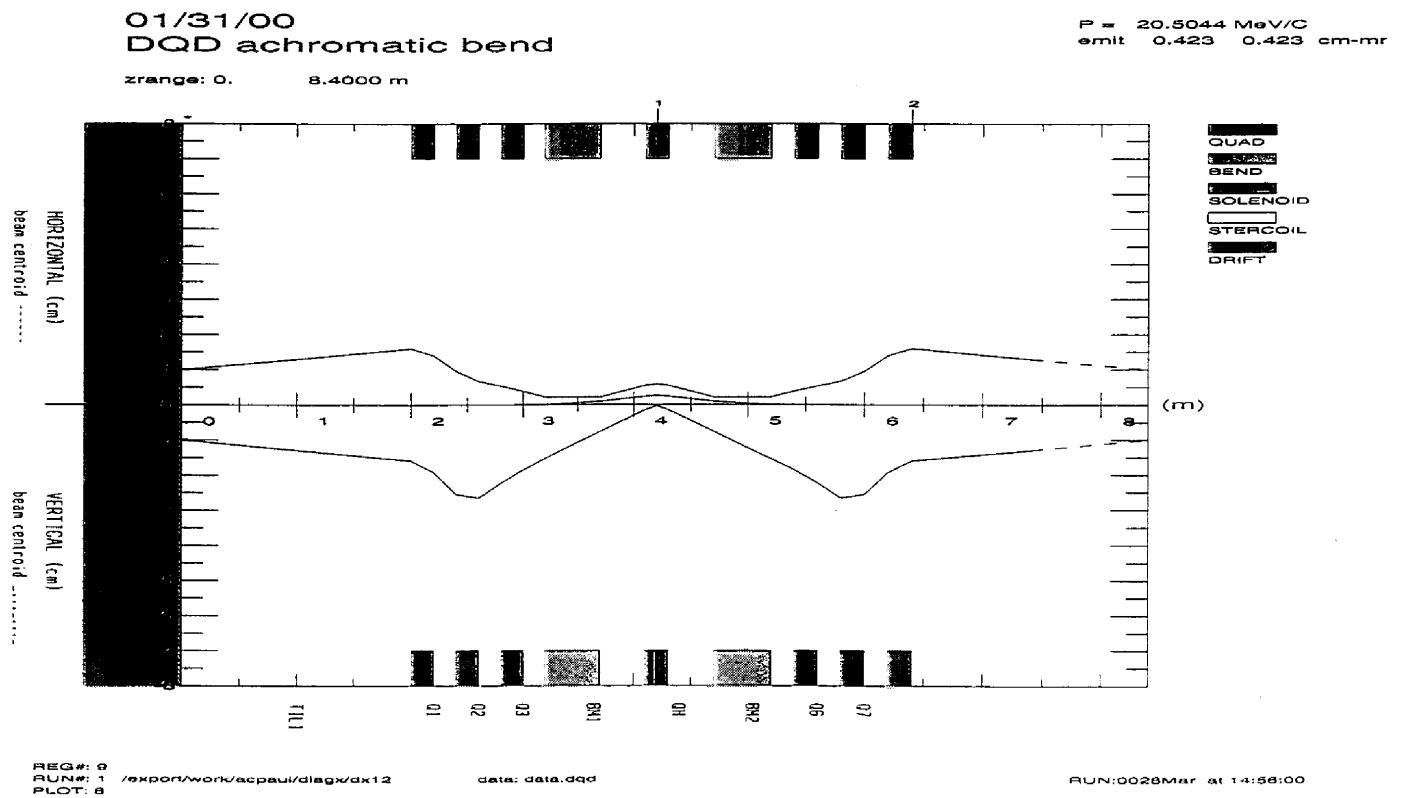
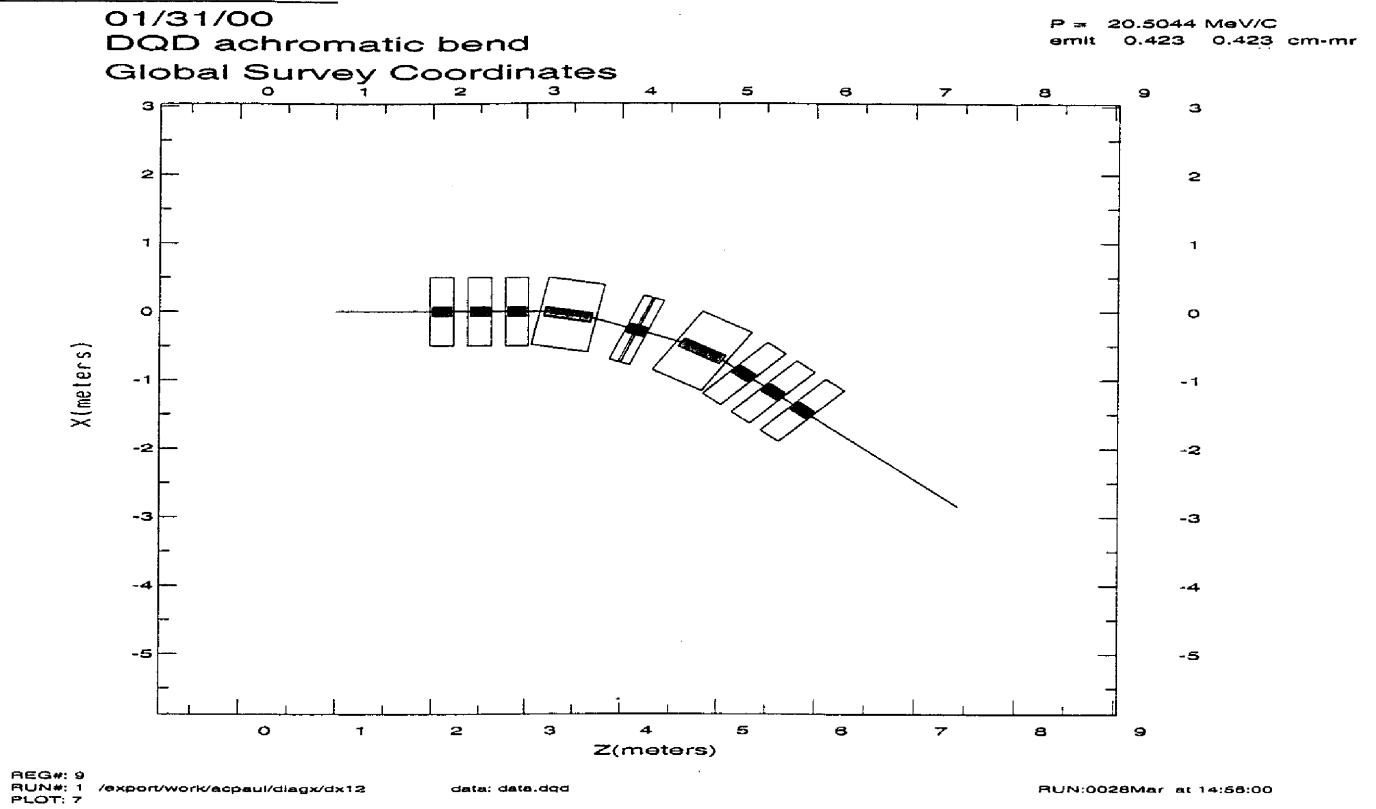


Figure 5) Dipole Quadrupole Dipole achromatic bend system with quadrupole triplet matching sections.

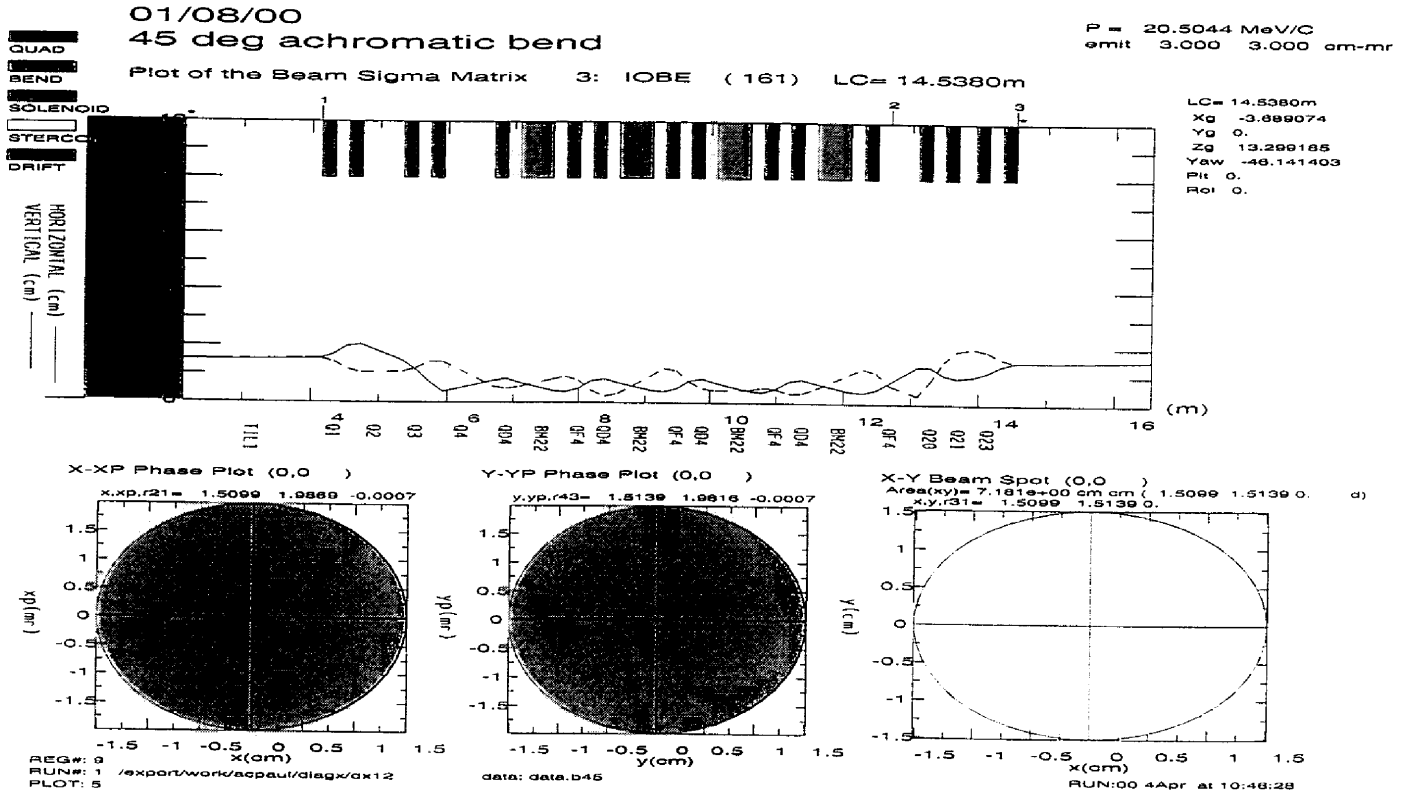
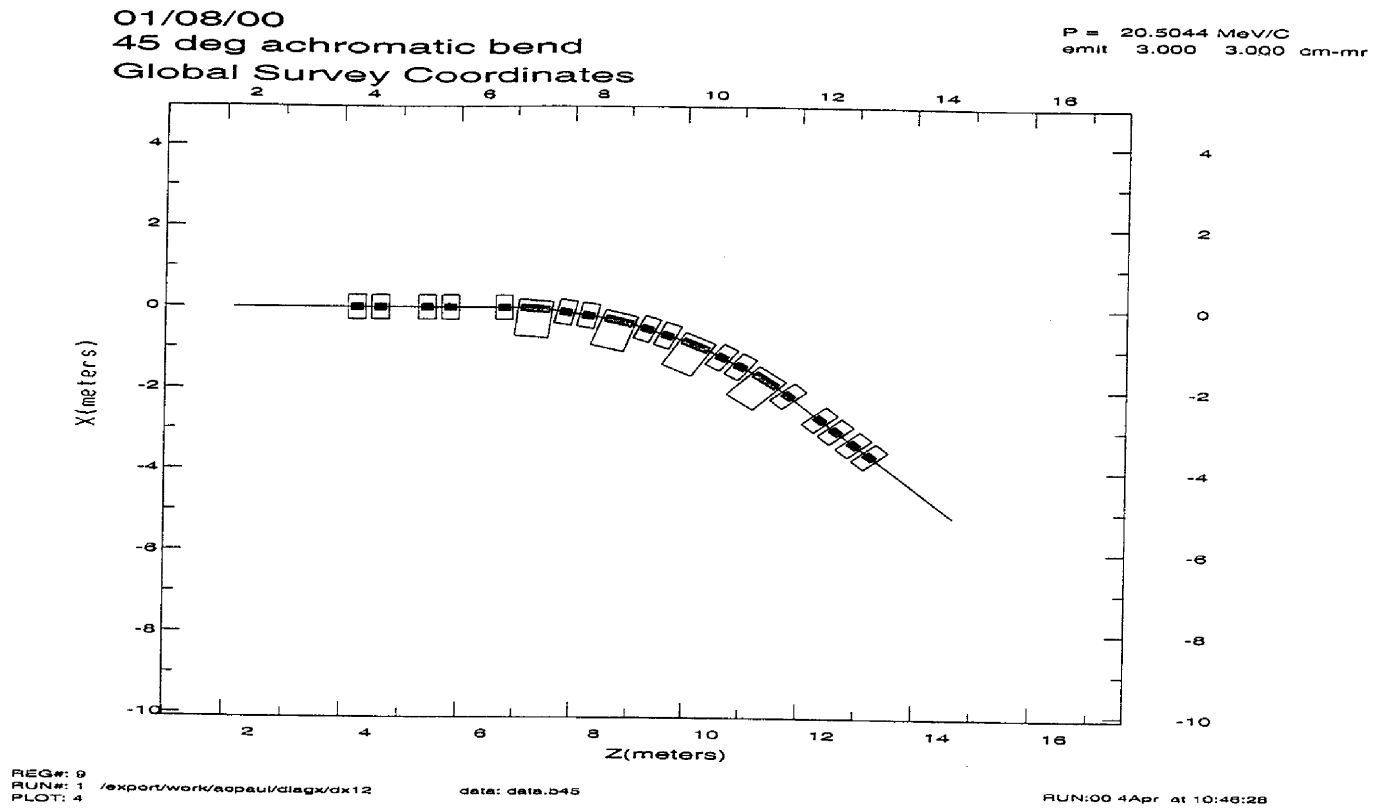
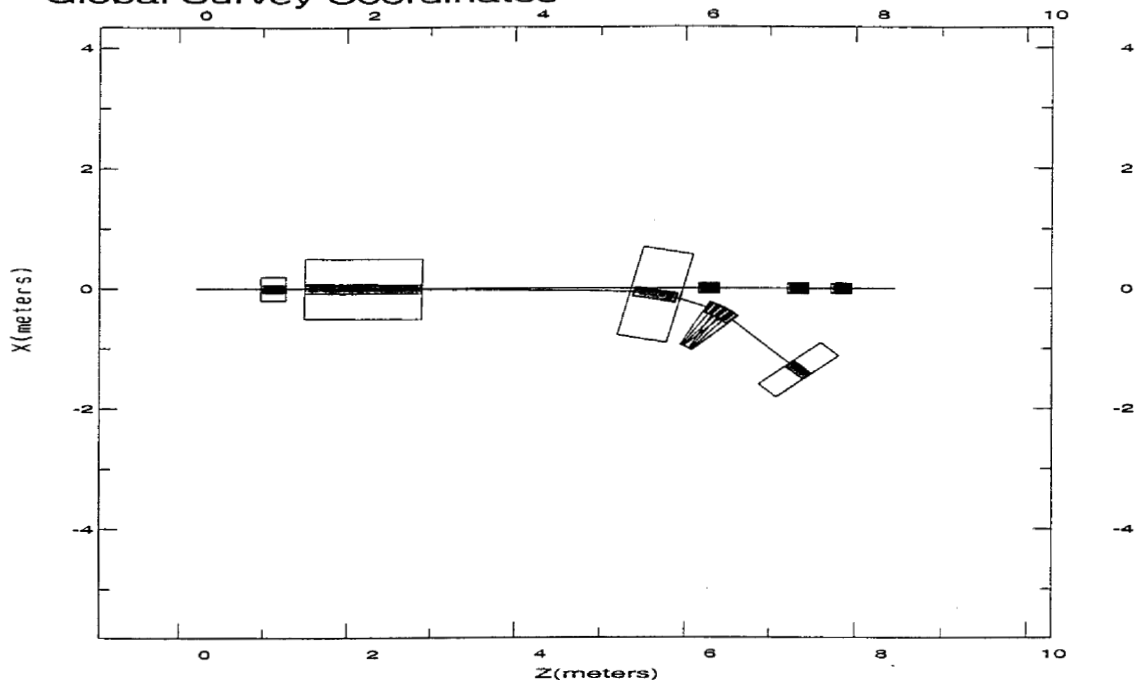


Figure 6) Four QDQ sections with phase advance $\pi/2$. Achromatic bend with quadrupole matching sections.

03/29/00
45d kicker (off) quad septum - dump beamline
Global Survey Coordinates

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



REQ#: 1
RUN#: 2 /export/work/acpaul/diagx/dx12
PLOT: 13

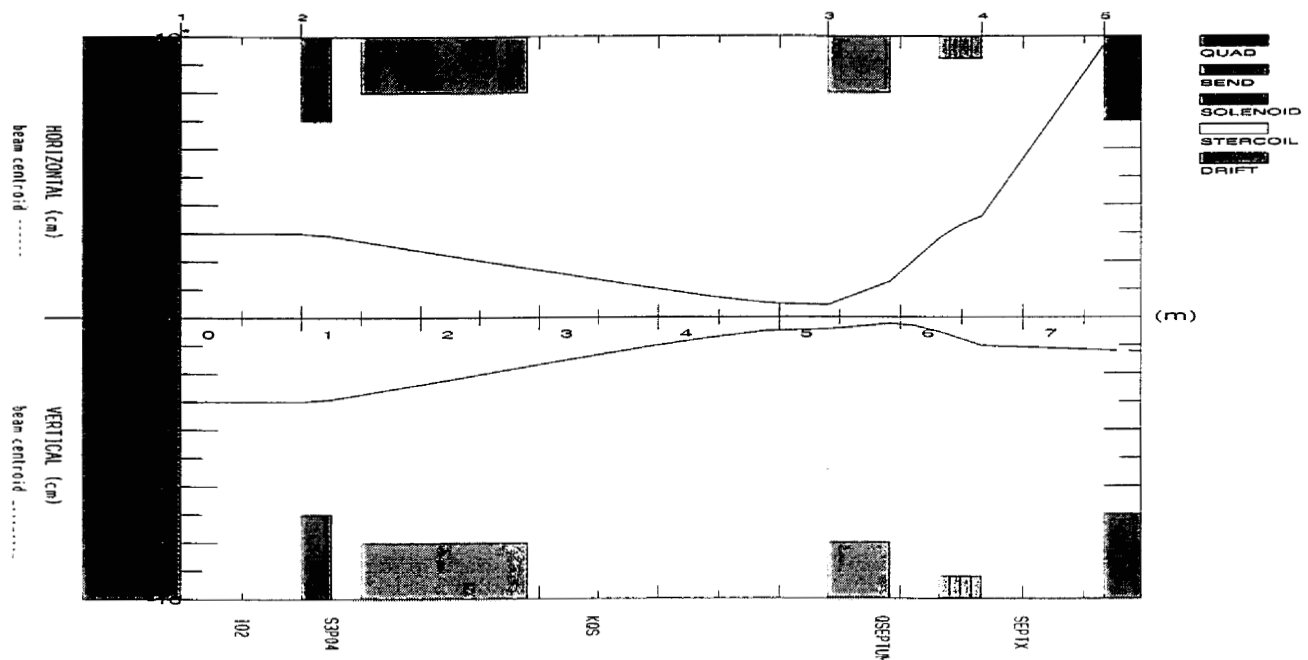
data: data.kqa

RUN:00 5Apr at 12:17:39

03/29/00
45d kicker (off) quad septum - dump beamline

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr

zrange: 0. 7.9616 m



REQ#: 1
RUN#: 2 /export/work/acpaul/diagx/dx12
PLOT: 14

data: data.kqa

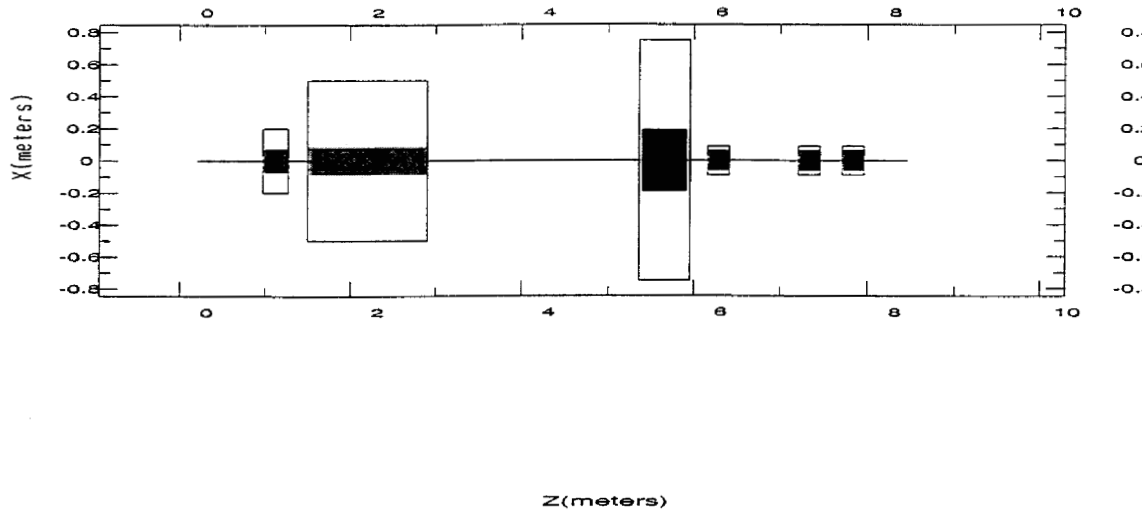
RUN:00 5Apr at 12:17:39

Figure 7) The kicker quadrupole septum block. The kicker kicks sections of the beam into the straight ahead line. The unkicked portions are deflected by the bias dipole of the kicker into the quadrupole septum off axis. That bends the beam into a dipole septum that increases the deflection to 45 degrees. The beam is then deposited in a dump.

03/29/00

kicker quad septum - kicked straight ahead
Global Survey Coordinates

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



REG#: 9
RUN#: 3 /export/work/acpsul/diag/dx12
PLOT: 16

data: data.kqs

RUN:00 5Apr at 12:17:39

03/29/00

kicker quad septum - kicked straight ahead

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr

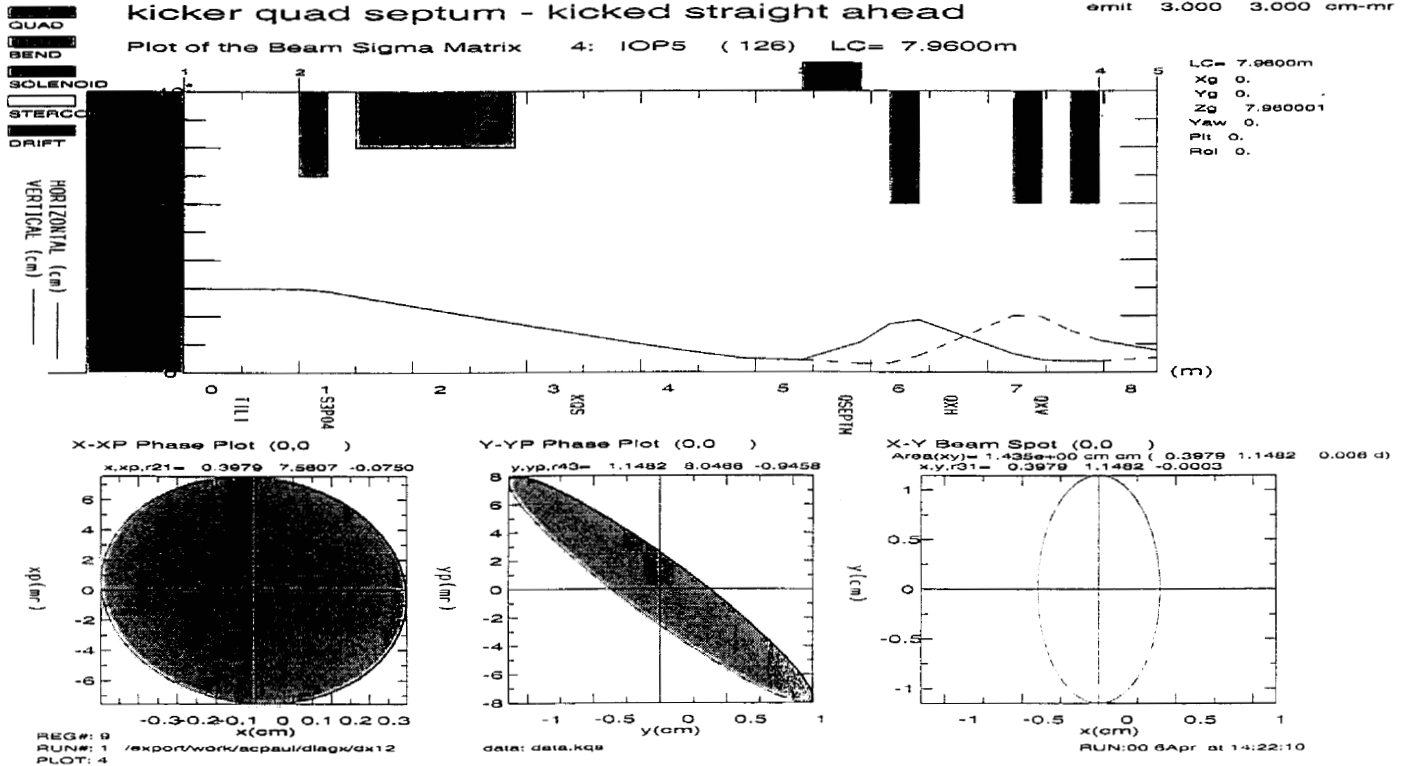


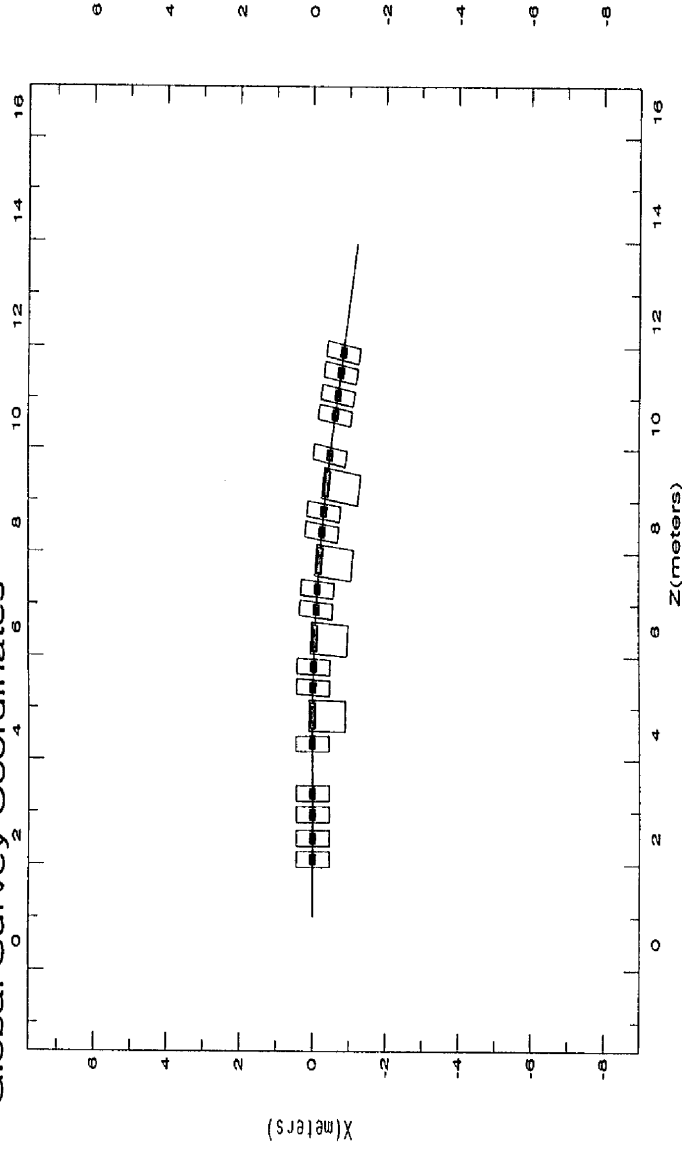
Figure 8) The kicker quadrupole septum block kicks sections of the beam into the straight ahead line.

The beam phase space and image is shown at the exit of the KQS system, IP05. The beam entering the system has a matched radius of 3 cm and is focused to small size by S3 just in front of the quadrupole septum.

04/04/00

10 deg achromatic bend Global Survey Coordinates

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



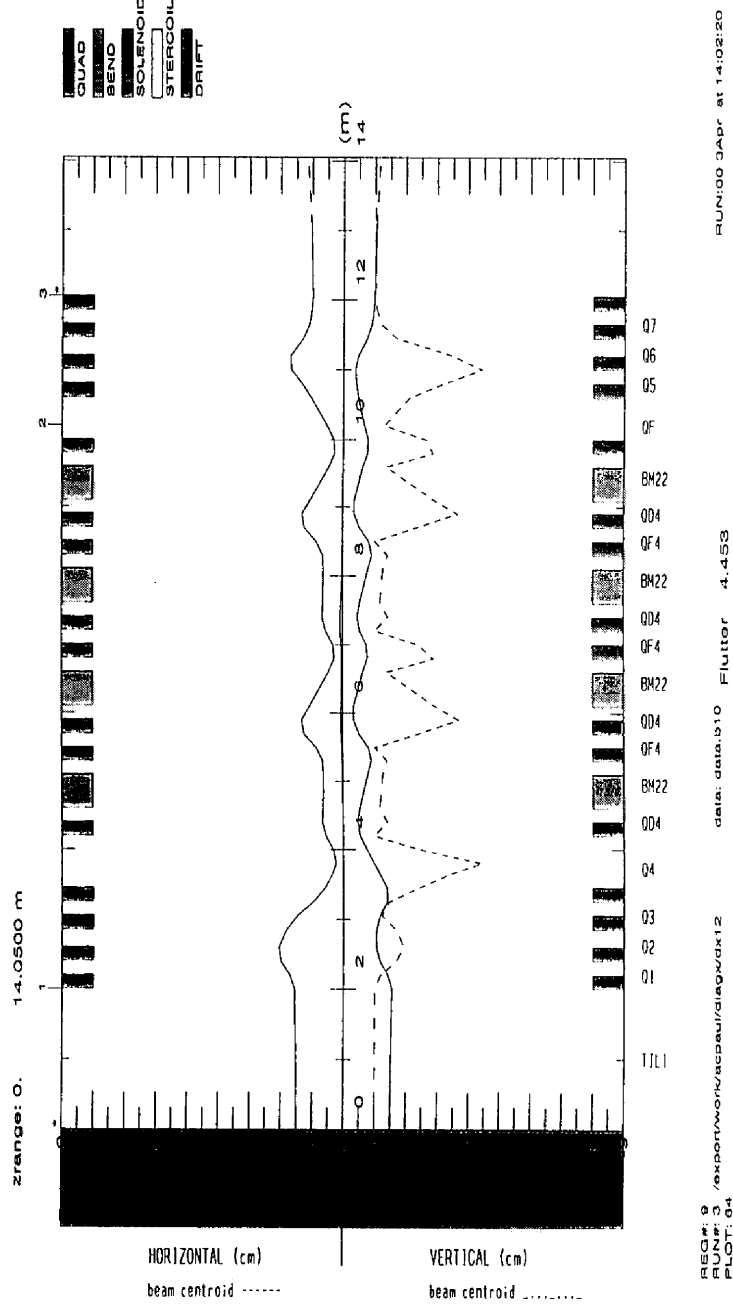
REQ# 9
RUN# 3
PLOT: 83

data: data.b10

RUN:00 3Apr at 14:02:20

04/04/00 10 deg achromatic bend

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



REQ# 9
RUN# 3
PLOT: 84

data: data.b10

RUN:00 3Apr at 14:02:20

Figure 11. 10 degree achromatic bend used to set the elevation and pitch angle of the diagnostic x beamline.

A) The geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells.

B) The beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .

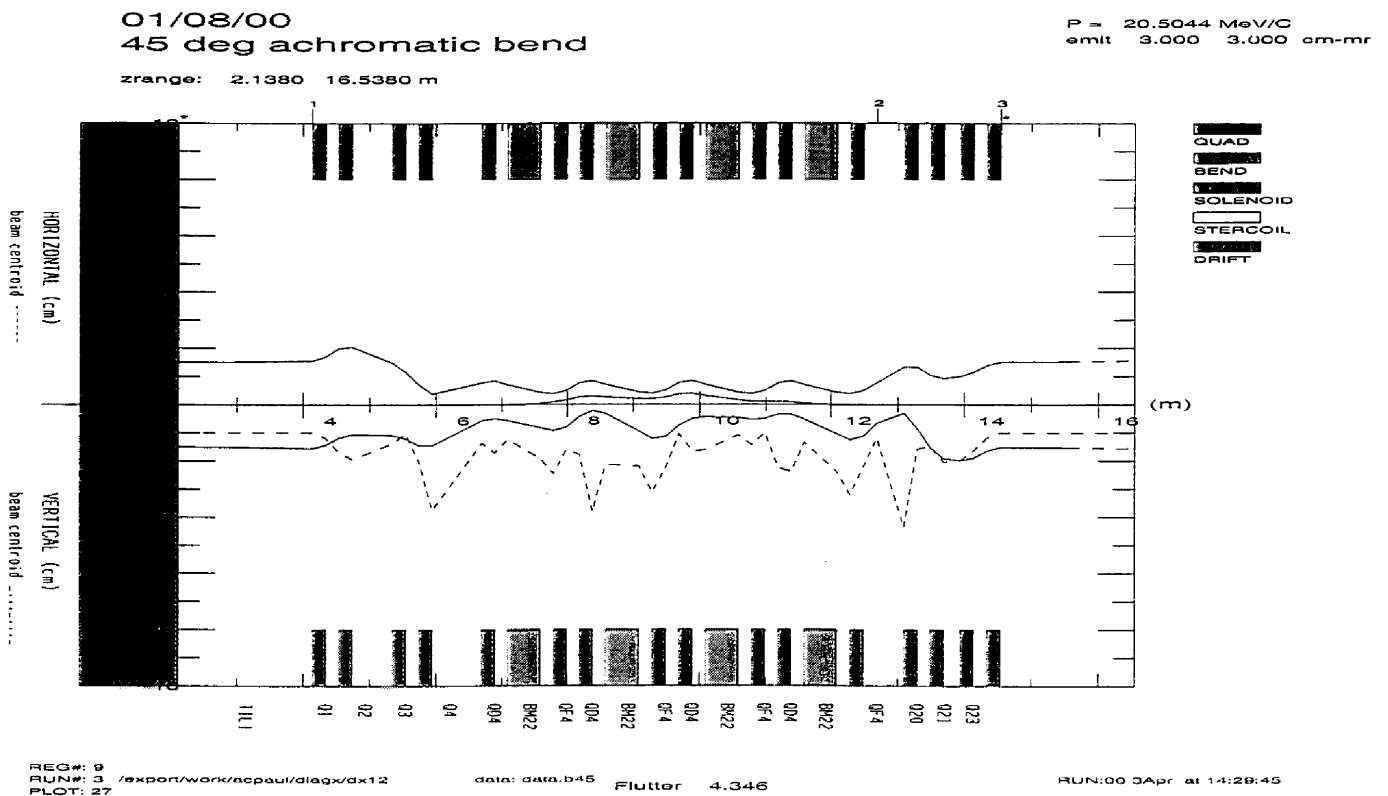
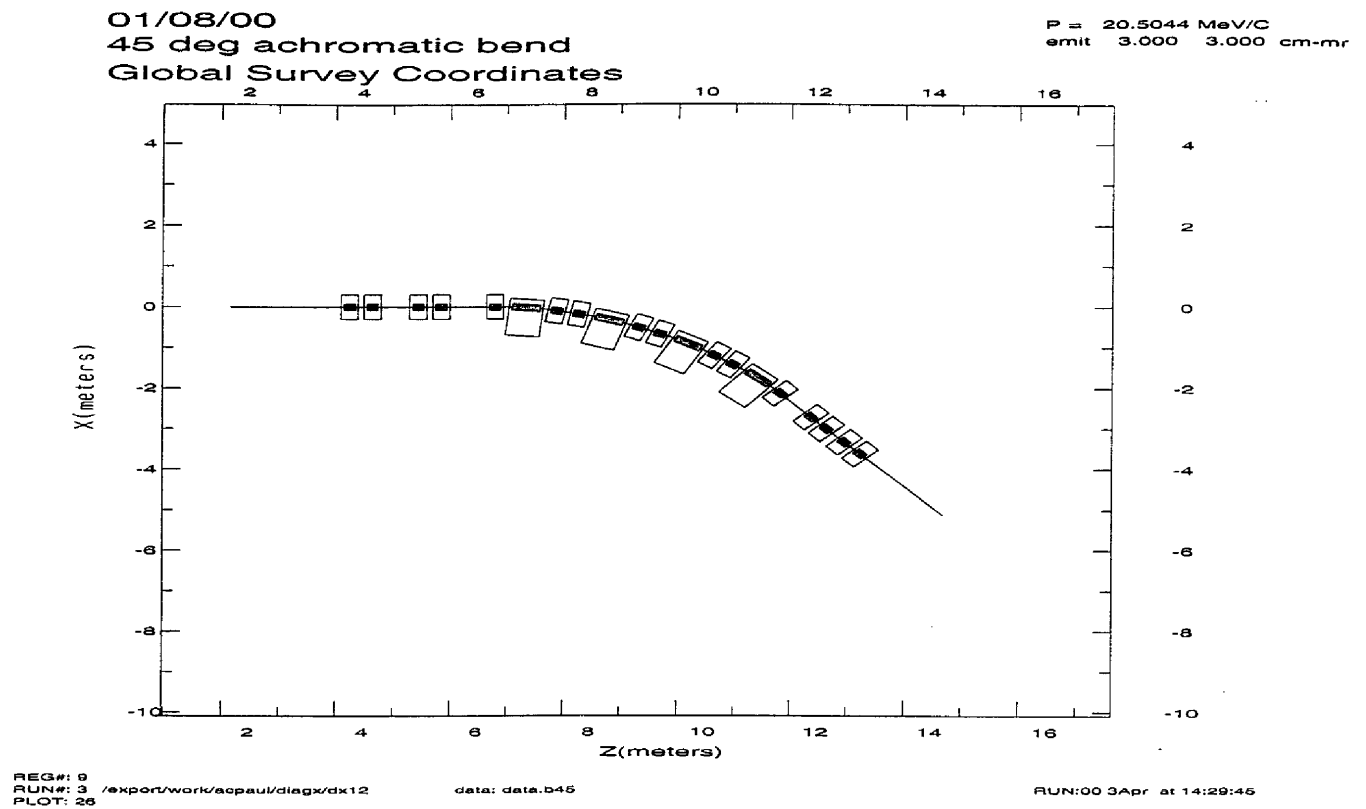


Figure 13. 45 degree achromatic bend used to set the yaw and pitch angle of the beamline 2, 4, 6, and 8.

A) The geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells.

B) The beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .

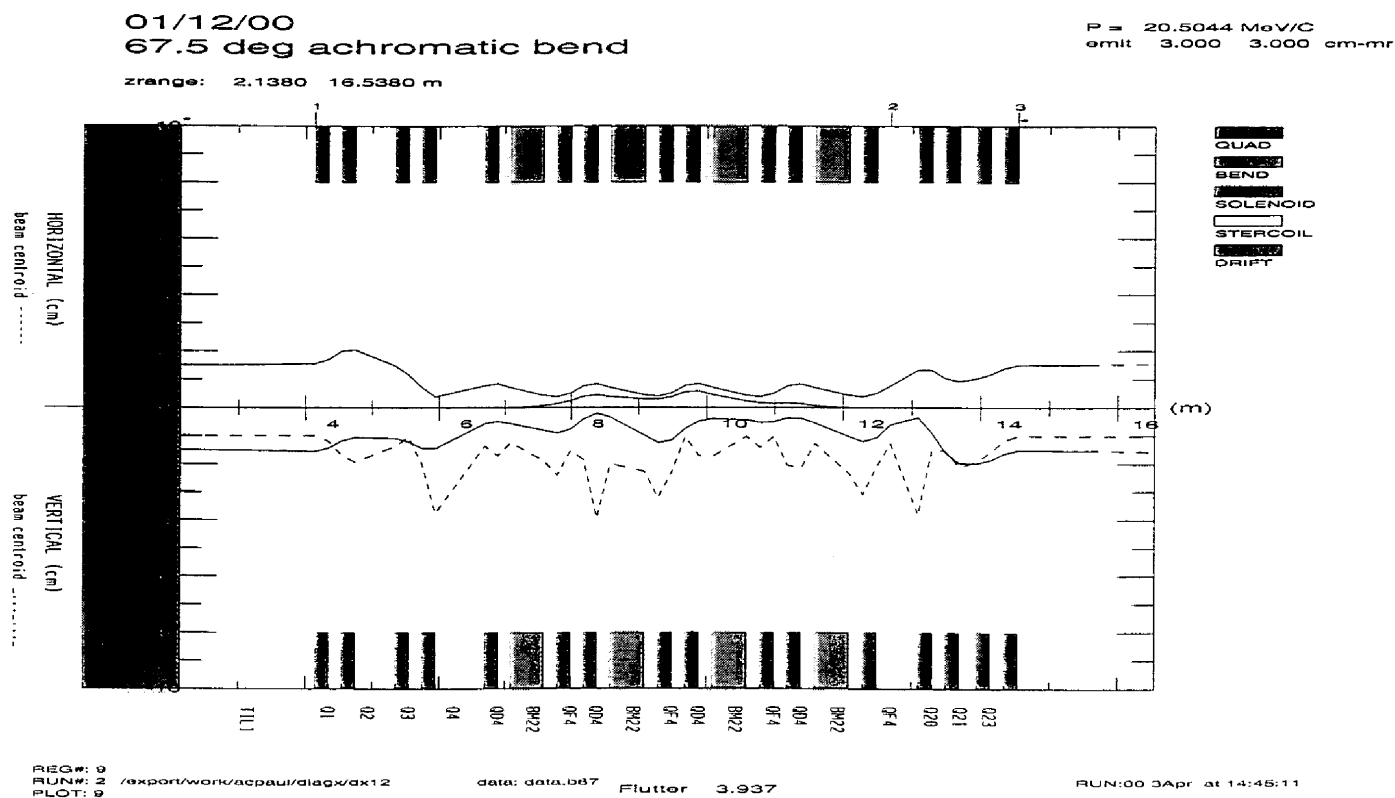
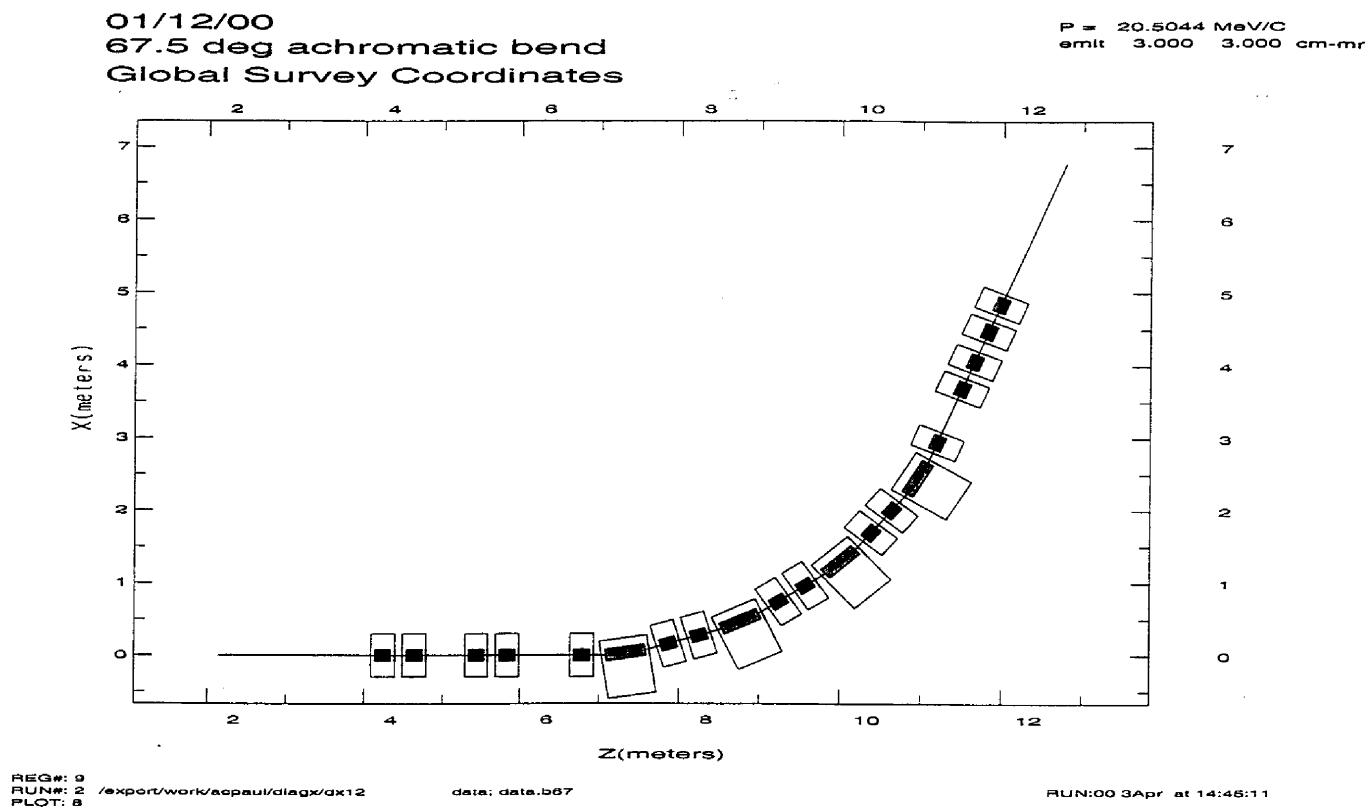


Figure 15. 67.5 degree achromatic bend used to set yaw index for beamlines 5-8 with respect to lines 1-4.

A) The geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells.

B) The beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .

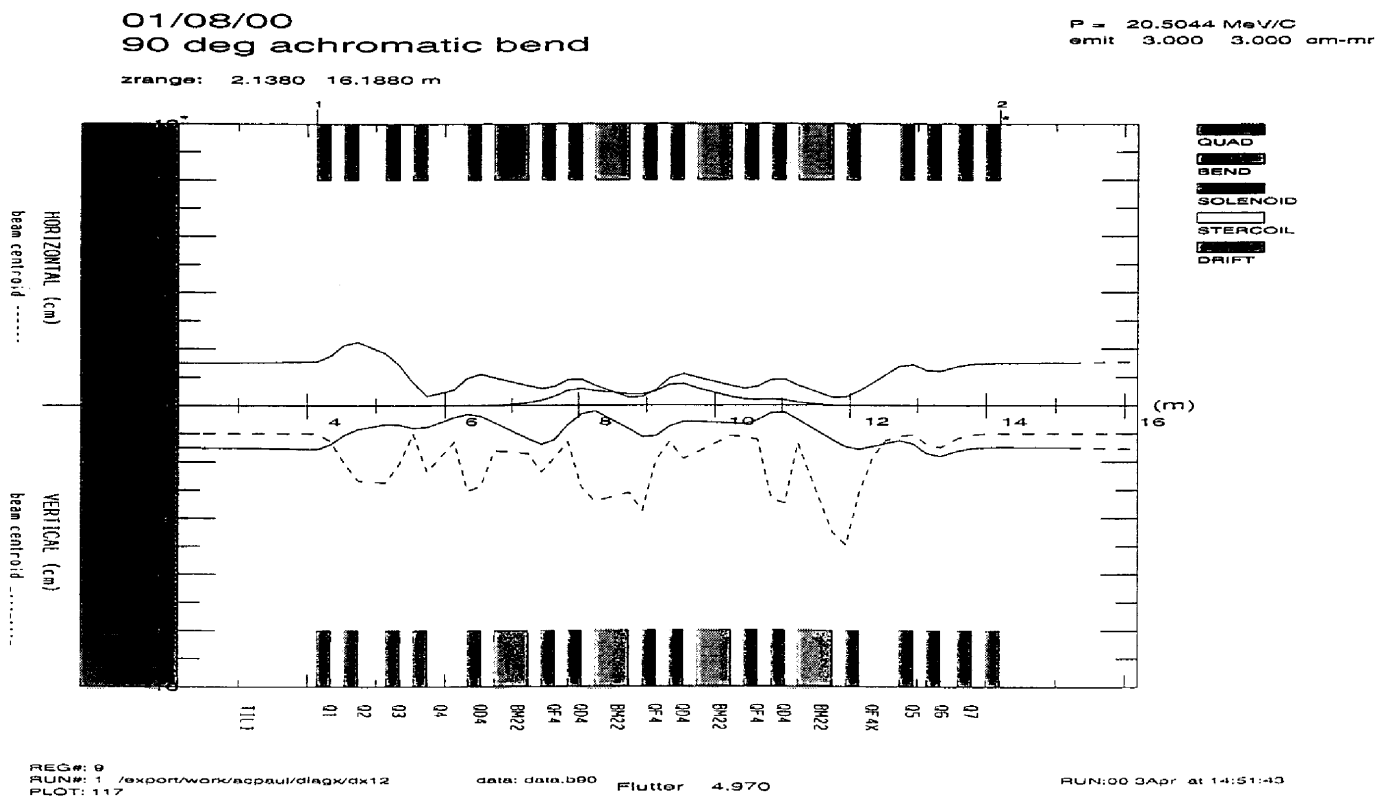
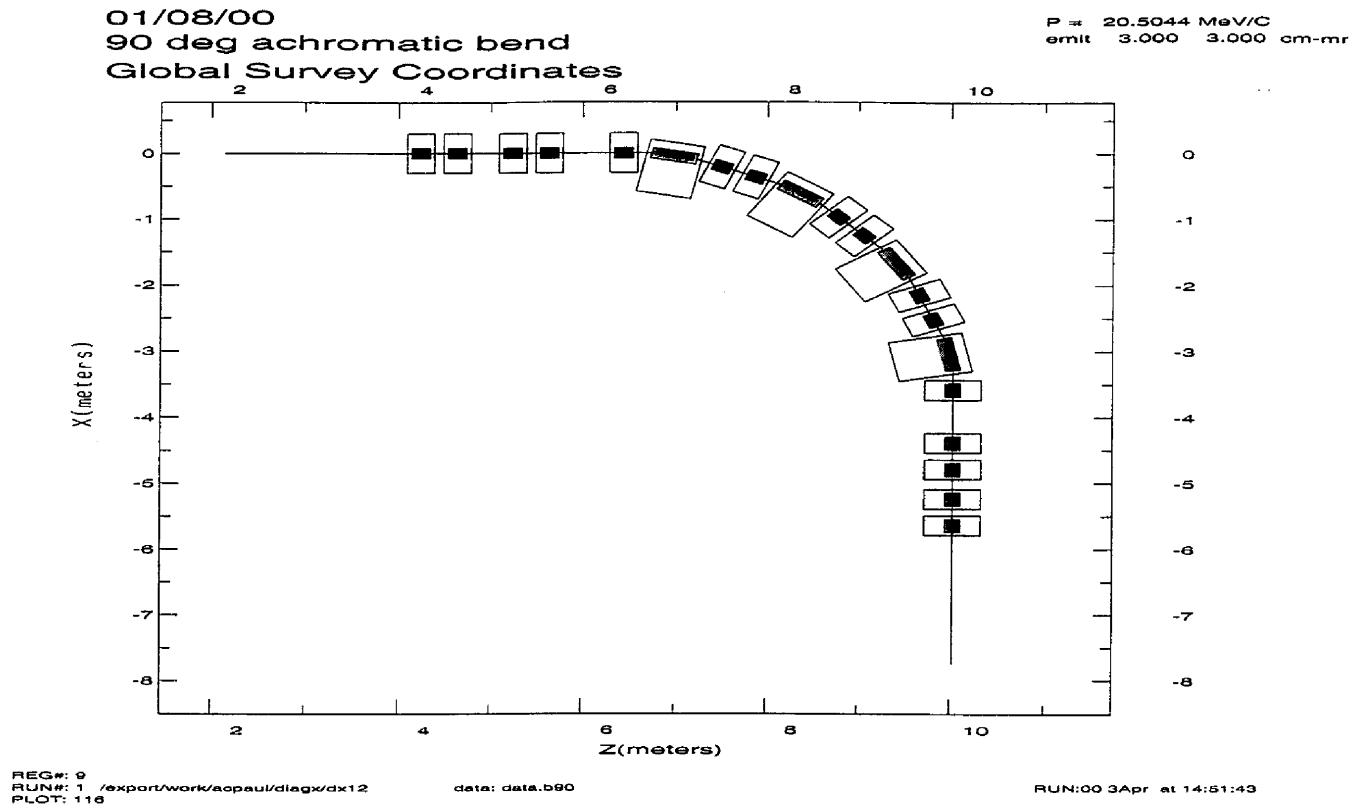


Figure 17. 90 degree achromatic bend based on four fold symmetry of the QDQ $\pi/2$ phase advance system.
A) The geometric layout showing the four quadrupoles that match into and out of the four bend (QDQ) cells.
B) The beam envelope, horizontal above and vertical below the centerline. The dashed curve is the beam flutter, the maximum of x/y or y/x .

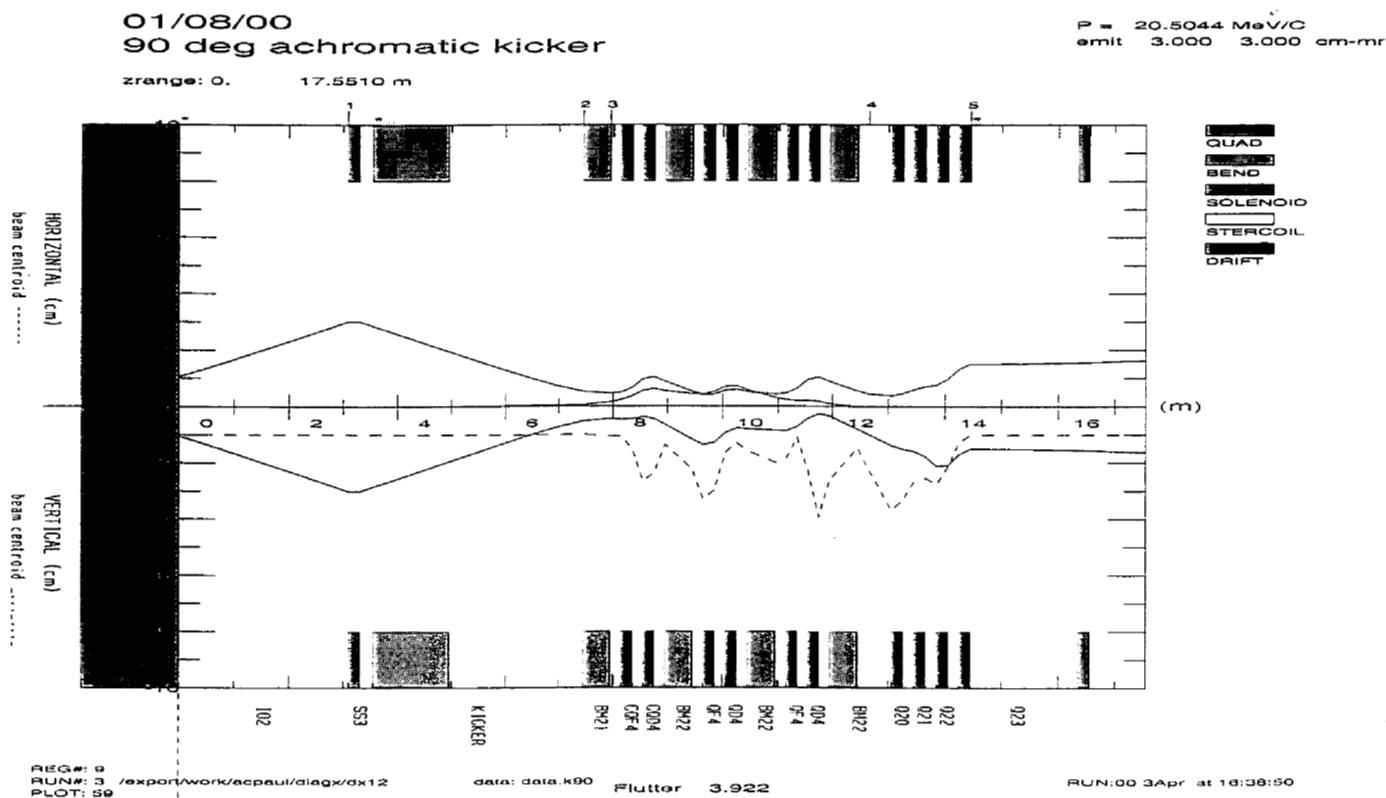
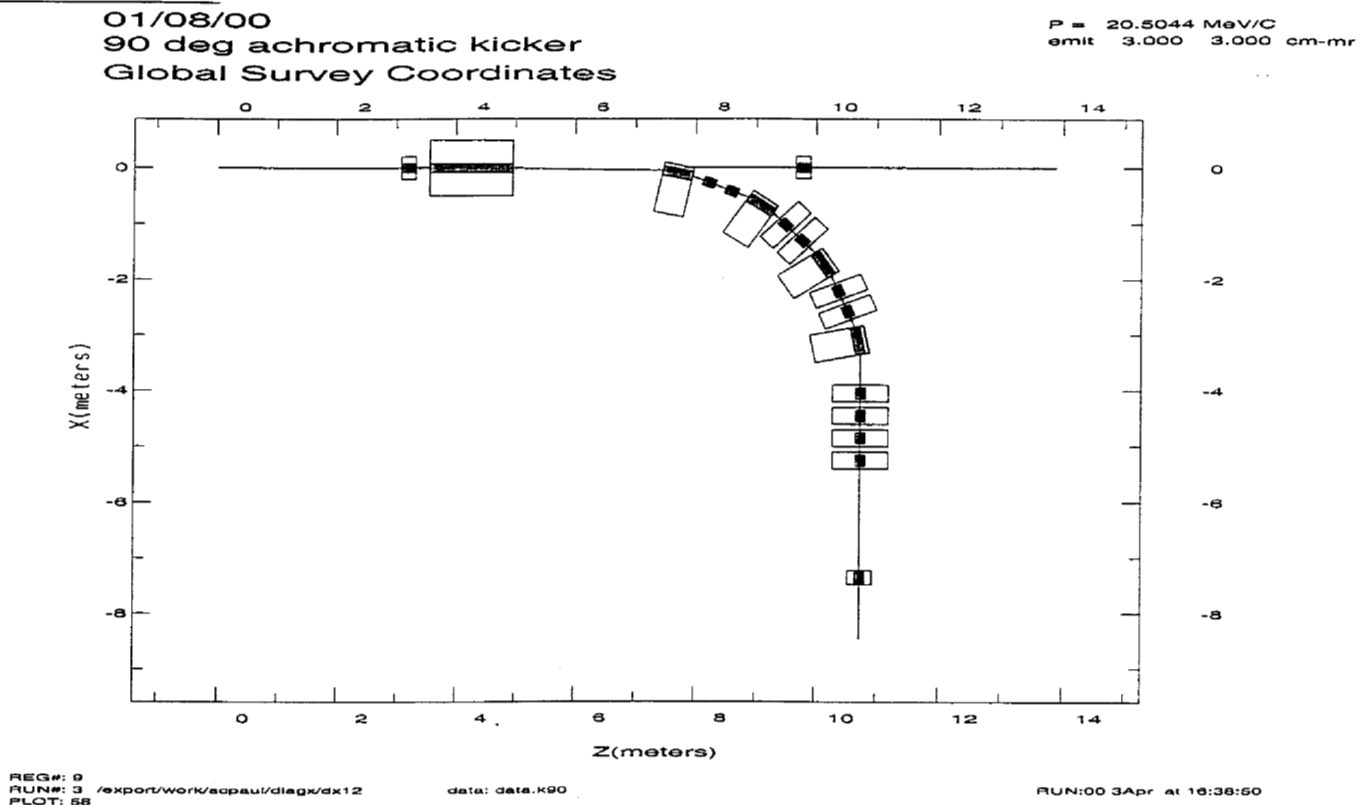
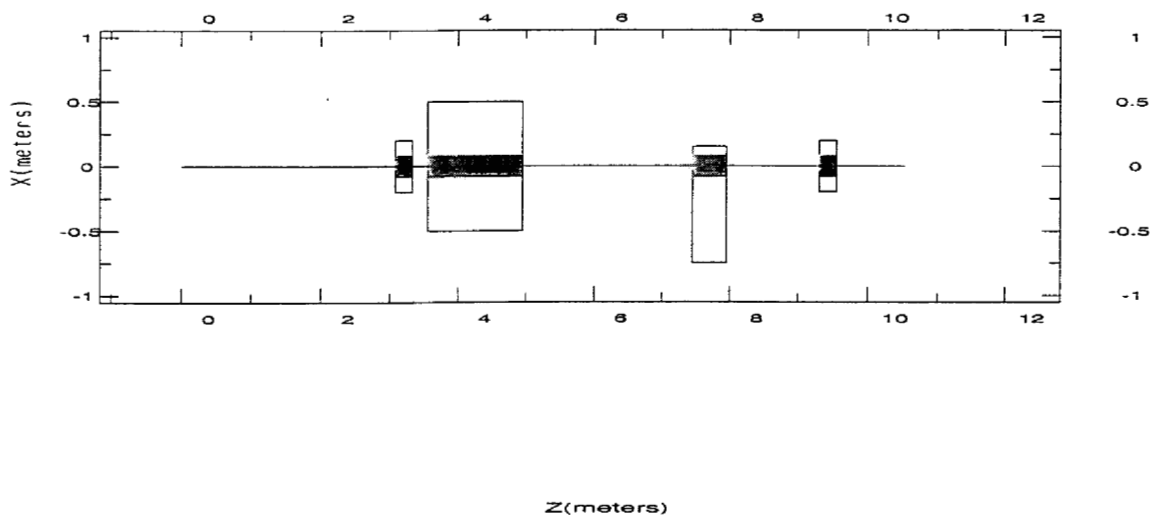


Figure 19) 90 degree kicker achromatic bend. The kicker and dipole septum form first cell of the 4 cells.
A) beam line plot, location 1 starts the block, location 5 ends the block at the exit of the last quadrupole.
B) Geometry showing the kicked 90 degree bend and the unkicked straight ahead beamlines.

01/08/00
90d kicker off - straight ahead section
Global Survey Coordinates

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



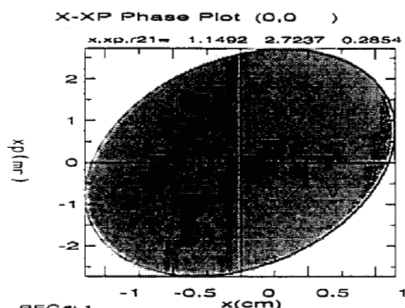
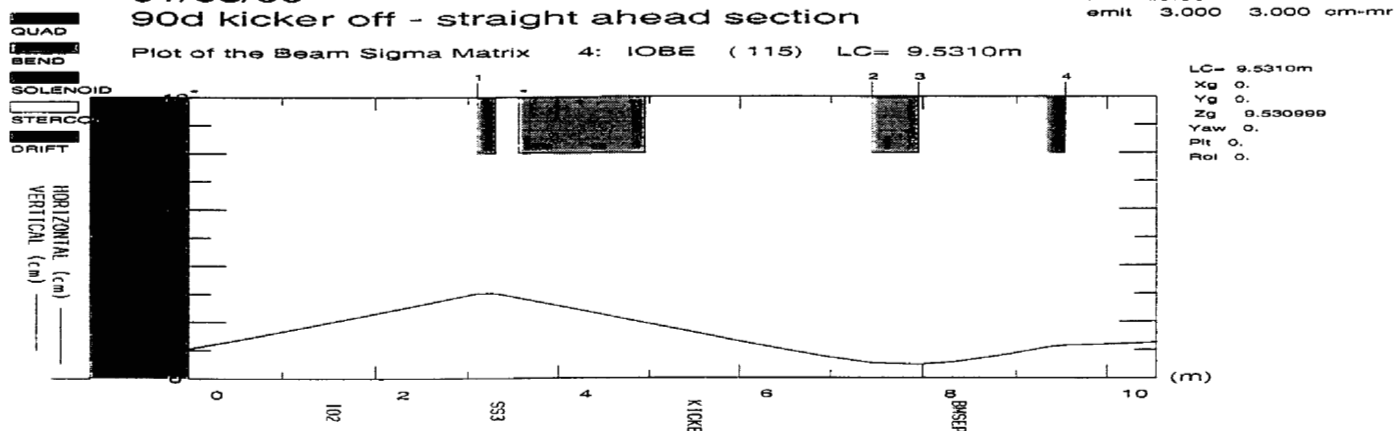
REG#: 1
RUN#: 4 /export/work/acpaul/diag/dx12
PLOT: 63

data: data.k90

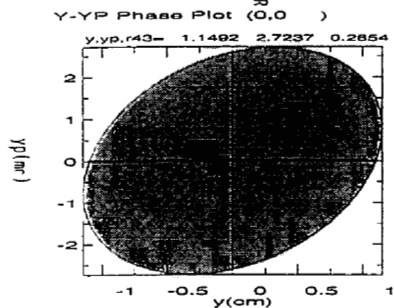
RUN:00 3Apr at 16:38:50

01/08/00
90d kicker off - straight ahead section

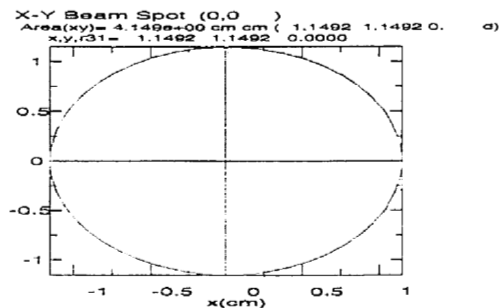
P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



REG#: 1
RUN#: 4 /export/work/acpaul/diag/dx12
PLOT: 62



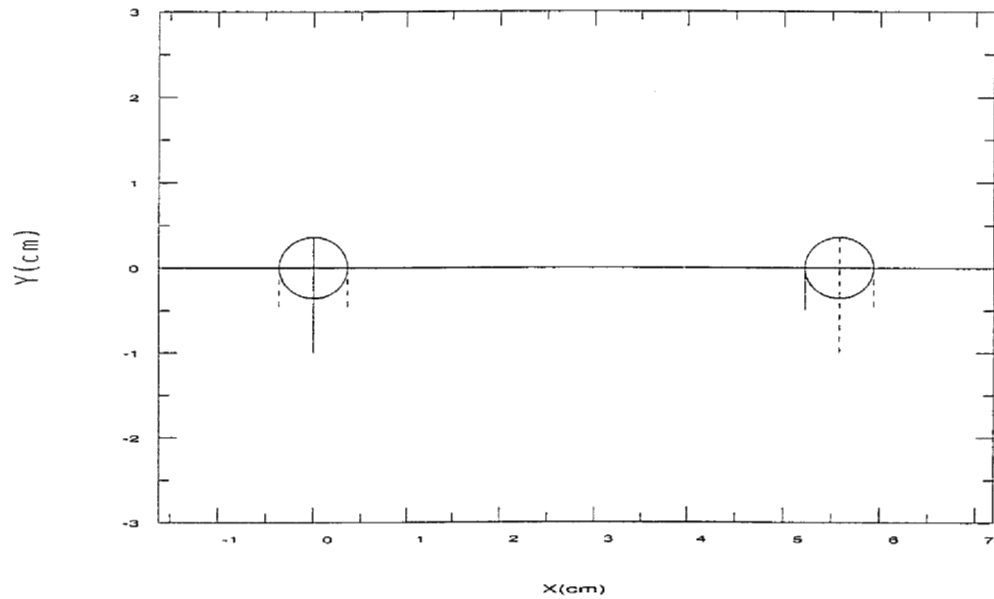
data: data.k90



RUN:00 3Apr at 16:38:50

Figure 20) K90 block showing the unkicked beam trace and geometry layout.

Kicked and un-Kicked beams



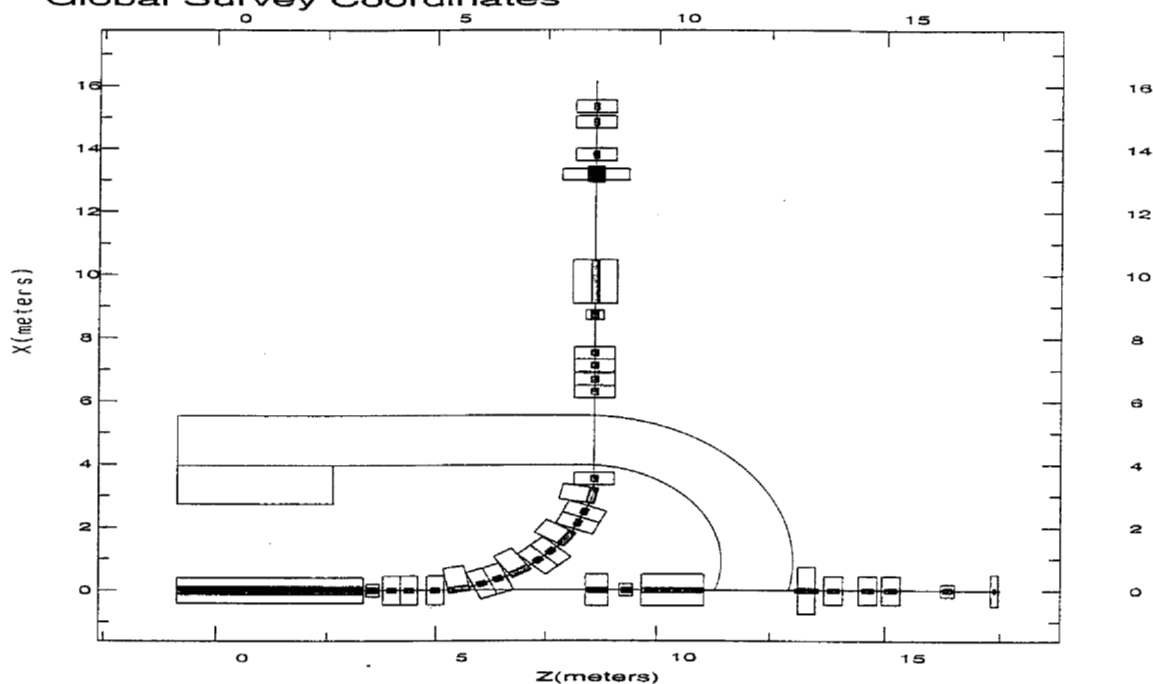
/export/work/acpaul/diag/dx12/Figs
/export/work/acpaul/diag/dx12/Figs

A.C.Paul
3-Apr-00

Figure 21) Transverse beam size for the kicked and un-kicked beams showing size and centroid displacements. The septum of the K90 block and vacuum walls of the vessel must be in the space between the two beams.

10/06/99
DARHT2 - Diagnostic X-breakout
Global Survey Coordinates

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr



REQ#: 9
RUN#: 1 /export/work/acpaul/diagx/dx12
PLOT: 7

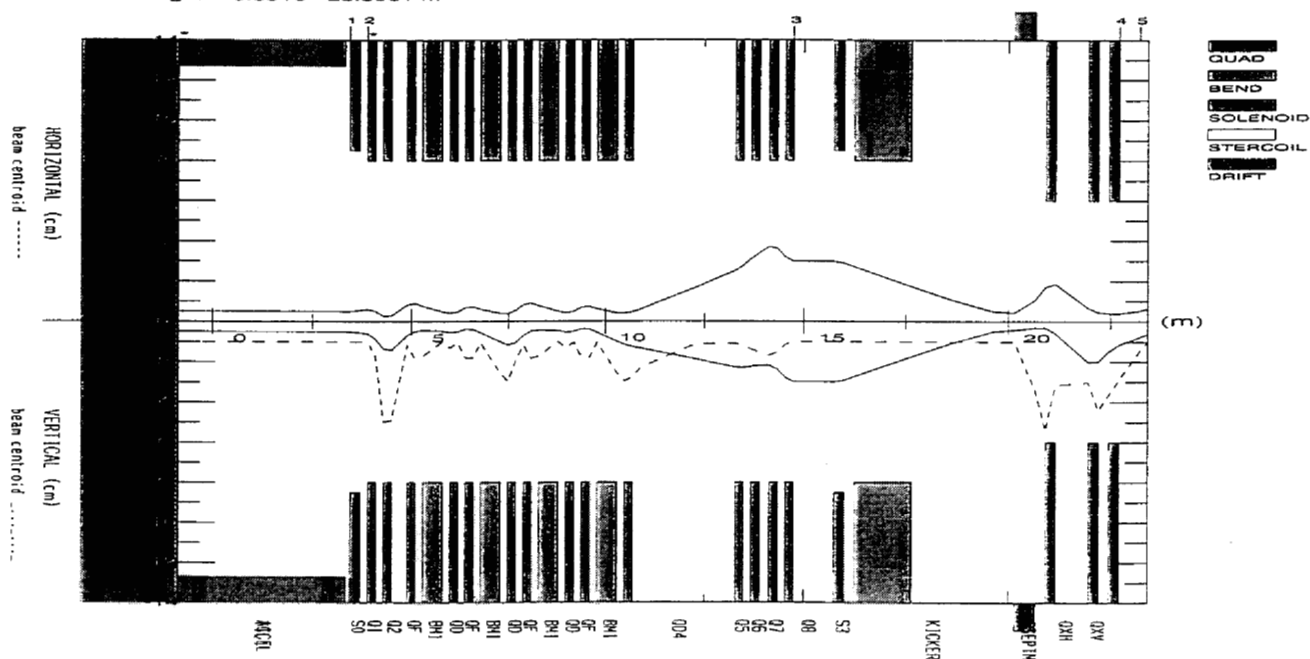
data: data.a90

RUN:00 3Apr at 15:18:20

10/06/99
DARHT2 - Diagnostic X-breakout

P = 20.5044 MeV/C
emit 3.000 3.000 cm-mr

zrange: -0.8510 23.3981 m



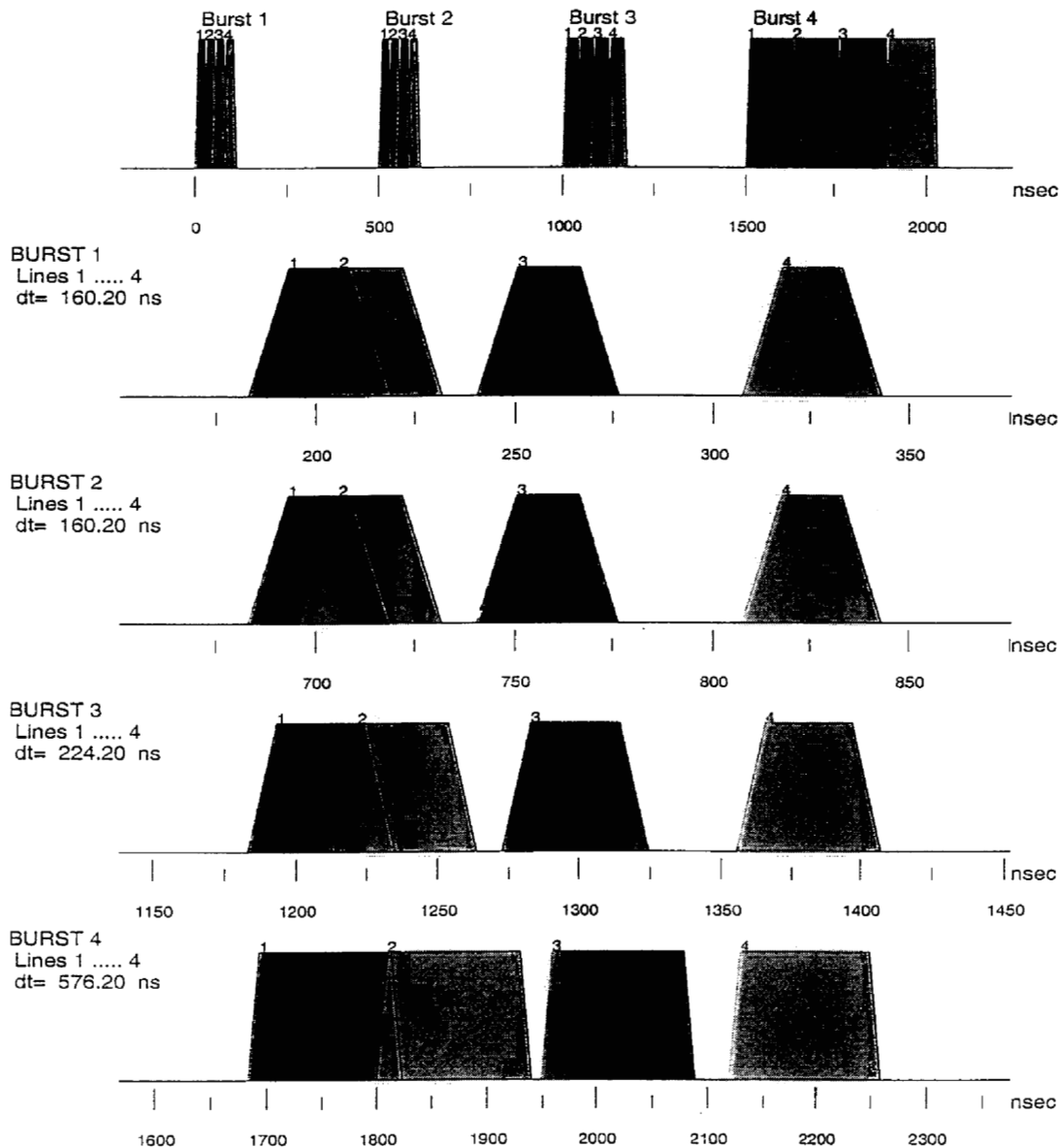
Diagnostic X Timing

```

rise fall / pulse1 pulse2 pulse3 pulse4 (nsec)
rise fall time 10.00 10.00 nsec
Pulse duration: 16.00 16.00 32.00 120.00 nsec.
Burst separation: 0.0 500.0 1000.0 1500.0 nsec.

```

Lc(m)= 97.33 93.37 98.95 111.18 136.90 184.09 189.57 201.90
Ks3(m)= 3.33 42.45 60.87 69.67 67.20 103.10 147.50 156.30
Kicker Order 1 2 3 4 5 6 7 8



```
/export/work/acpaul/diagx/dx12
data.time
```

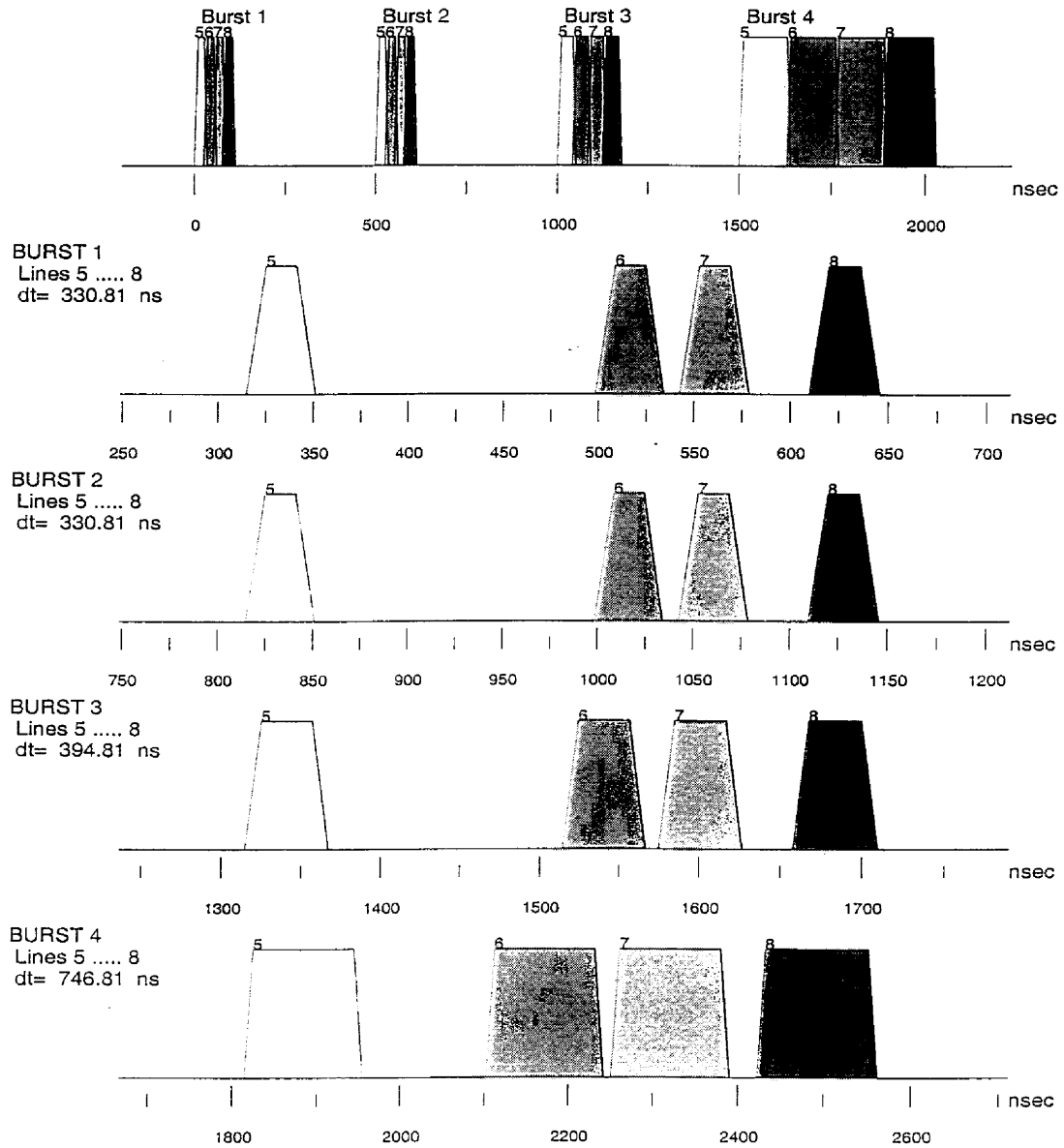
01/08/00 A.C.Paul
30-Mar-00

Figure 24) Timing beamlines 1 through 4 fired in sequential order. A) division of the 2usec accelerator pulse. B) arrival time profile for burst 1. C) arrival time profile for burst 2. c) arrival time profile for burst 3. D) arrival time profile for burst 4.

Diagnostic X Timing

rise fall / pulse1 pulse2 pulse3 pulse4 (nsec)
 rise fall time 10.00 10.00 nsec
 Pulse duration: 16.00 16.00 32.00 120.00 nsec.
 Burst separation: 0.0 500.0 1000.0 1500.0 nsec.

Lc(m)= 97.33 93.37 98.95 111.18 136.90 184.09 189.57 201.90
 Ks3(m)= 3.33 42.45 60.87 69.67 67.20 103.10 147.50 156.30
 Kicker Order 1 2 3 4 5 6 7 8



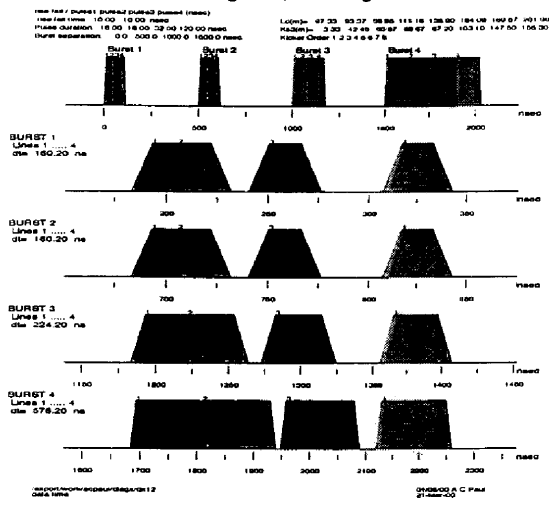
/export/work/acpaul/diagx/dx12
 data.time

01/08/00 A.C.Paul
 30-Mar-00

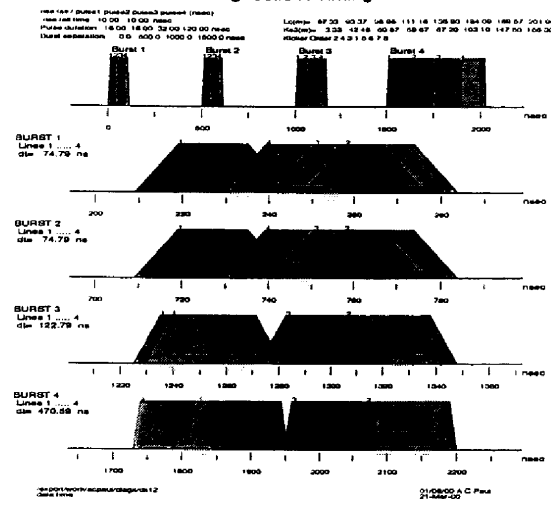
Figure 25) Timing beamlines 5 through 8 fired in sequential order. A) division of the 2usec accelerator pulse. B) arrival time profile for burst 1. C) arrival time profile for burst 2. c) arrival time profile for burst 3. D) arrival time profile for burst 4.

Figure 26) Beamlines 1 through 4 can be switched in any one of $4!$ sequences. The arrival time of the four pulses at their respective targets is controlled by that sequence, the length and therefore the transite time of the lines, and the selected pulse length. These 24 sequences are shown on the following four pages, six sequences per page in the order given in table 31, along with the time span for that sequence. The minimum time is for sequence 3 4 2 1.

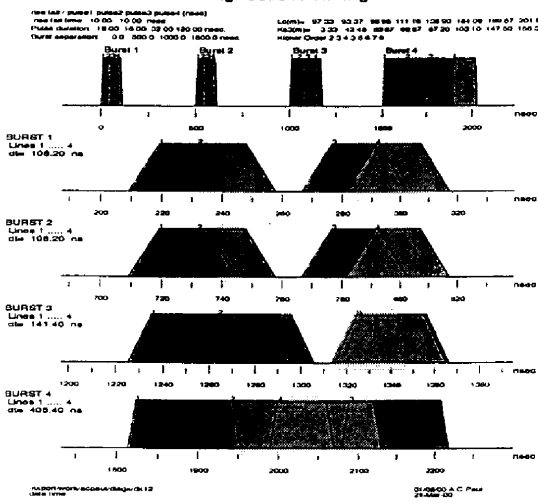
Diagnostic X Timing



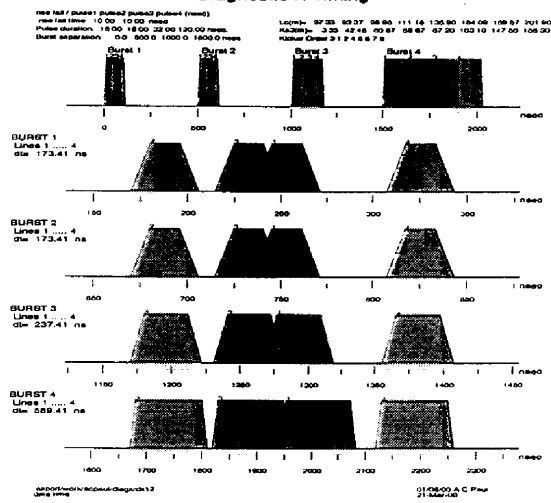
Diagnostic X Timing



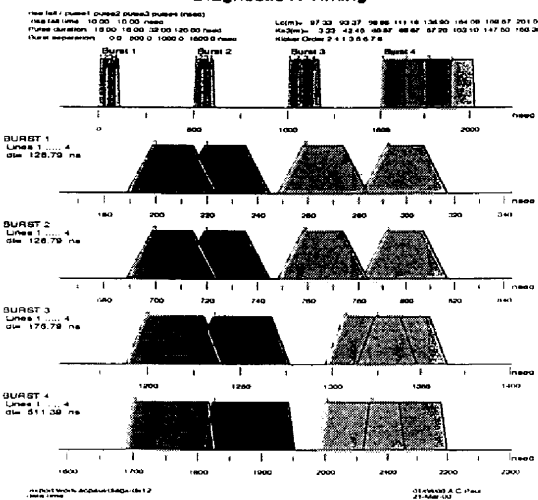
Diagnostic X Timing



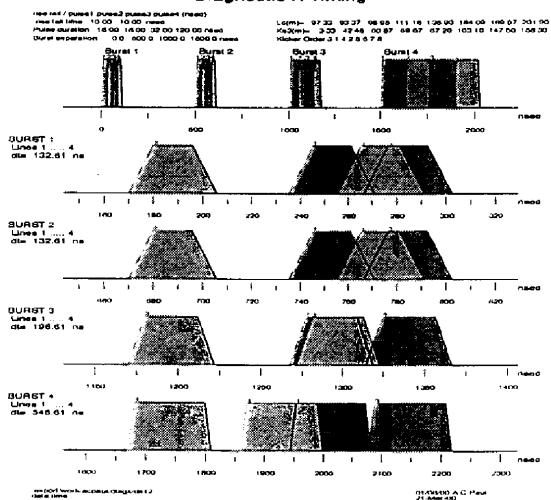
Diagnostic X Timing



Diagnostic X Timing



Diagnostic X Timing

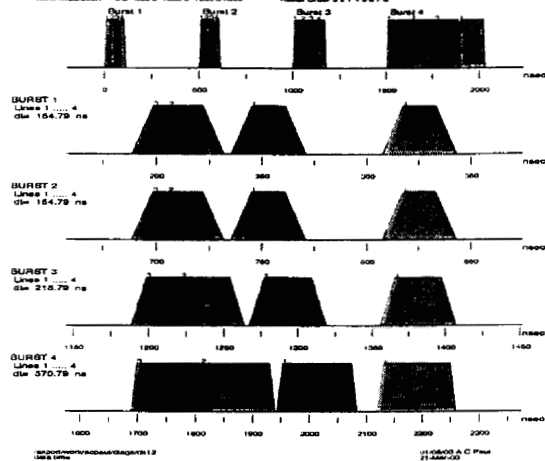


```

#end test / #end test / #end test / #end test / #end test / #end test /
#end test time 10 00 10 00 #end test
Phase duration: 14 00 14 00 33 06 120 00 #end test
Burn separation: 0 0 500 0 1000 0 1800 0 #end test

Lc(m)= 57.33 53.37 56.66 119.16 136.90 184.06 189.57 201.90
Kappa(m)= 3.33 42.46 60.67 66.67 67.70 103.10 147.00 106.00
Kappa Order 3 2 1 4 6 7 8

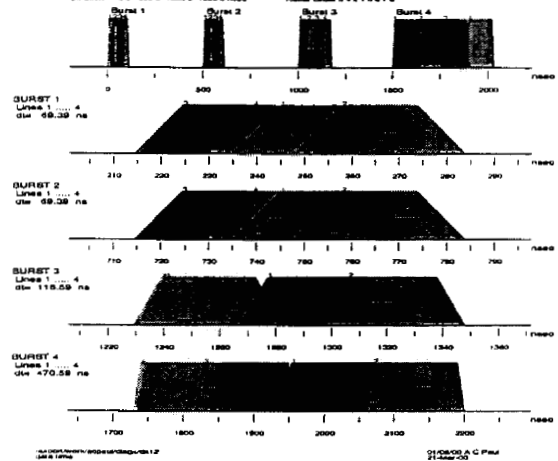
```



```

rfile tail / pump1 pump2 pump3 pump4 (rfile)
rfile tail rfile 10 00 00 00
Pump duration: 15 00 15 00 32 00 120 00 rfile
Curve separation: 0 0 000 0 1000 0 1500 0 rfile
Log(s): 97 32 80 37 26 90 111 16 126 90 184 09 189 07 201 90
Max(r/s): 3 33 +2 40 60 87 68 67 67 20 103 16 147 80 186 30
Riser Order 3 4 2 1 5 6 7 8

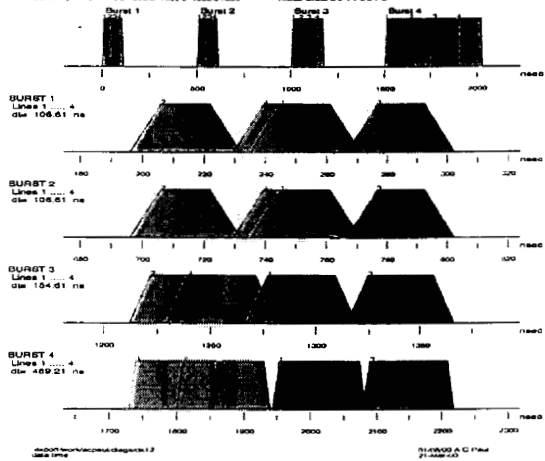
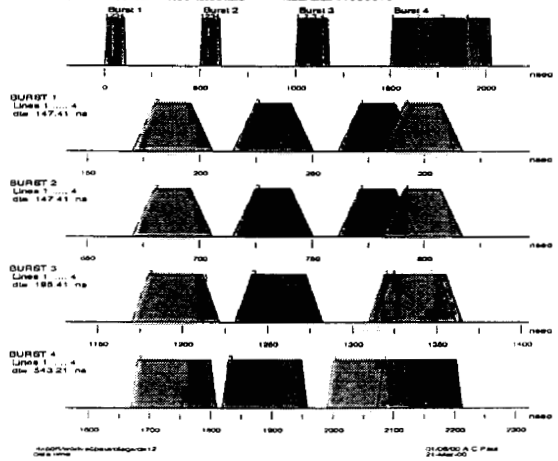
```



```

HIS tail / DUKE1 DUKE2 DUKE3 DUKE4 (HEAD)
map tail time 10 00 10 00 head
map duration 18 00 18 00 32 00 120 00 head
start acceleration 0 0 800 0 1000 0 1800 0 head

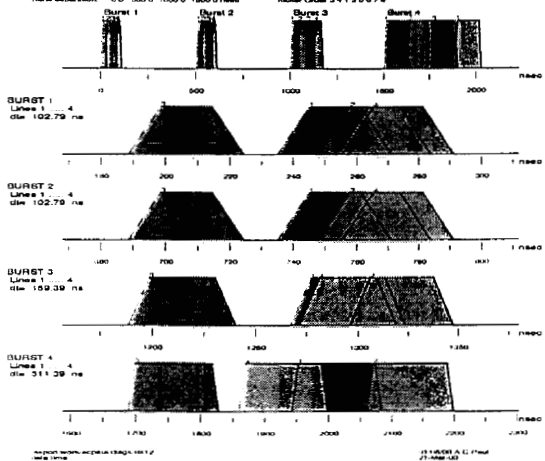
```

[illegible]

```

file test1 pulse2 pulse3 pulse4 (msec)
-----
reset time 10.00 10.00 msec
Pulse duration 16.00 16.00 32.00 120.00 msec
Pulse separation 0.0 500.0 1000.0 1800.0 msec
LC(4) = 97.33 93.37 98.96 111.18 126.90 184.08 179.87 201.90
MA(20) = 3.32 42.48 60.87 68.87 67.20 103.10 147.00 190.20
Ricker Order 3 4 1 2 5 6 7 8

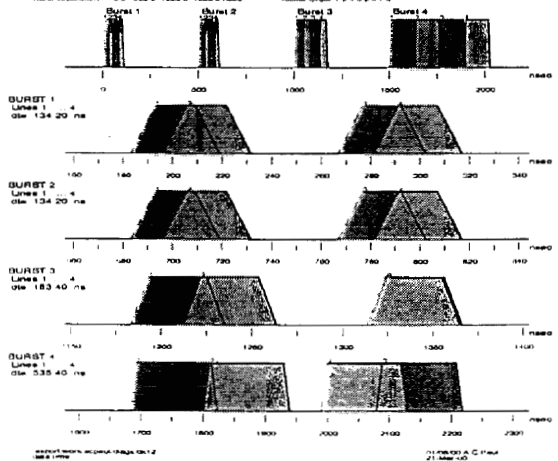
```



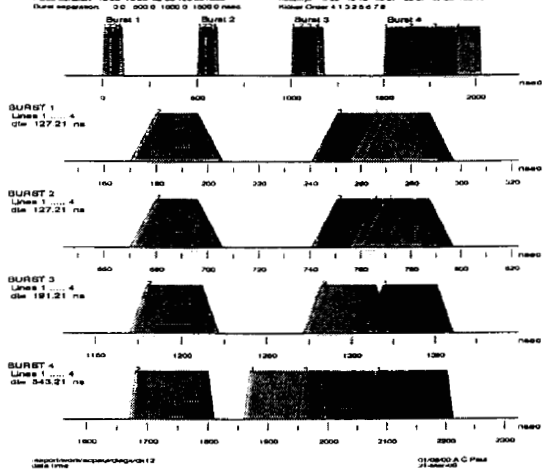
```

1# test pure1 pure2 pure3 pure4 (read)
1# test lat: 10.00 10.00 read
1# test duration: 16.00 16.00 32.00 120.00 read
1# test repetition: 0 0 500 0 1000 0 1500 0 read
1# (M)= 0.733 0.37 98.95 111.16 126.90 164.09 189.57 201.93
1# (M)= 2.33 42.48 60.67 69.67 67.70 103.10 147.60 186.30
1# test Order 1 2 3 4 5 6 7 8

```



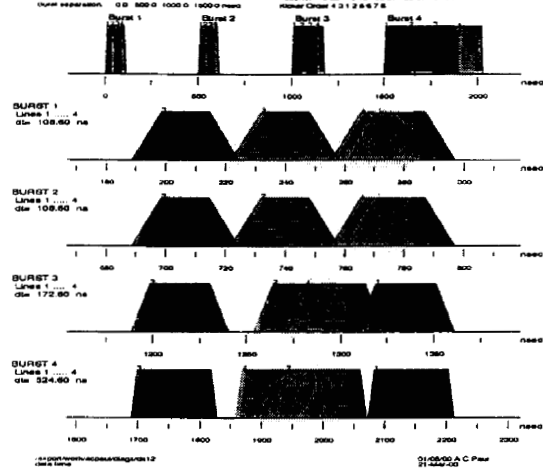
rule fail / success	success	success	success	success	reject
rule fail / time	1.00	1.00	1.00	1.00	
success / success	1.00	1.00	1.00	1.00	1.00



```

real fail / (push1 push2 push3 push4 / (read))
real fail time 10.00 10.00 nops
Push duration 18.00 18.00 32.00 120.00 nops
Log(m) 97.33 93.37 98.94 111.16 135.90 184.06 186.67 201.90
Max(m) 3.33 4.46 6.67 88.67 67.20 103.10 147.60 165.30

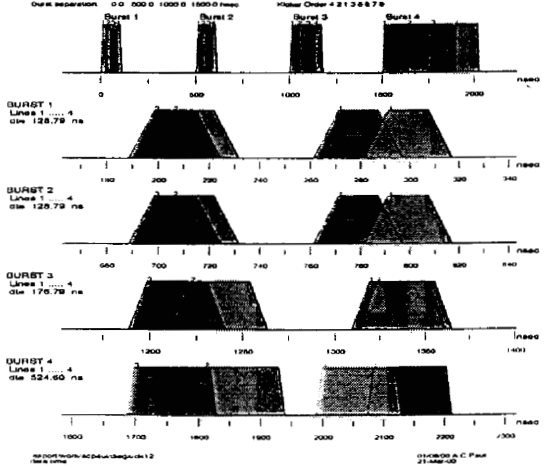
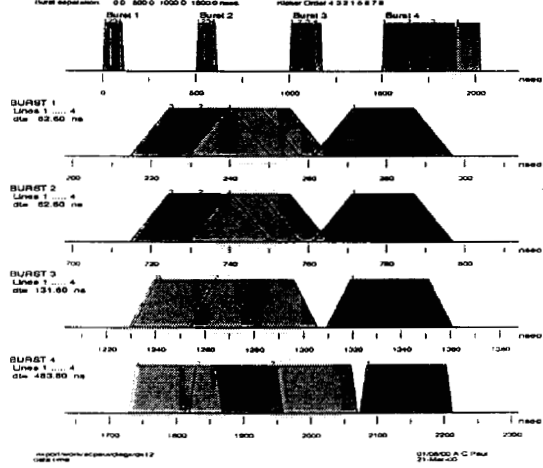
```



```

rep 1s / pulse1 pulse2 pulse3 pulse4 / (new)
rise fall time 10.00 10.00 ns
Pulse duration 15.00 15.00 32.00 120.00 ns

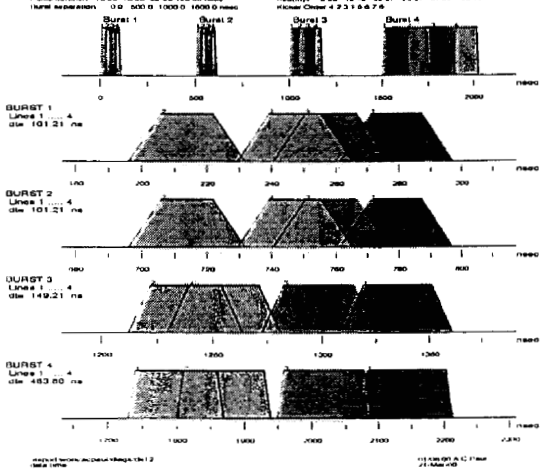
```

[illegible]

```

time left / (user1 puses2 puses3 puses4 / read)          LQ(M)  97.33  83.27  98.98  111.18  126.90  184.08  189.67  201.90
read task time  10.00  10.00 / read
(Pulse duration) 15.00 15.00 32.00 32.00 / read

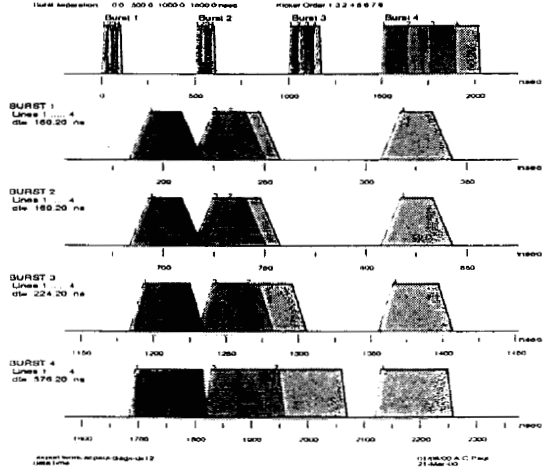
```



```

#000000 / SUMMIT Datab2 Datab3 Datab4 (Paved)
#near last time: 10:00 10:00 near
#near duration: 18:00 18:00 32:00 120:00 near

```



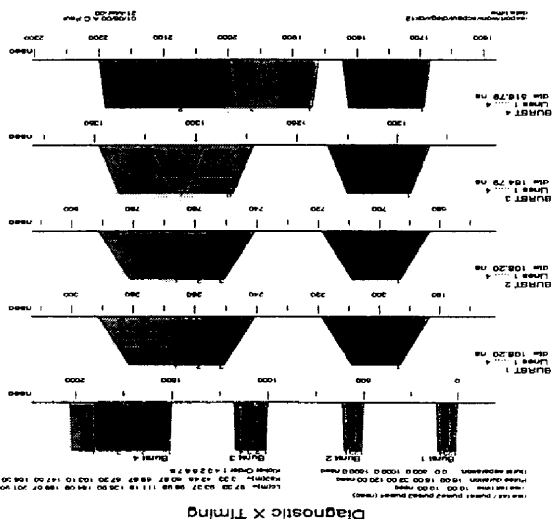
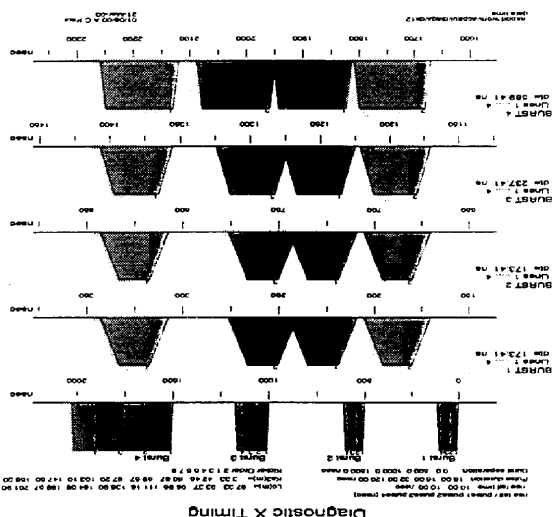
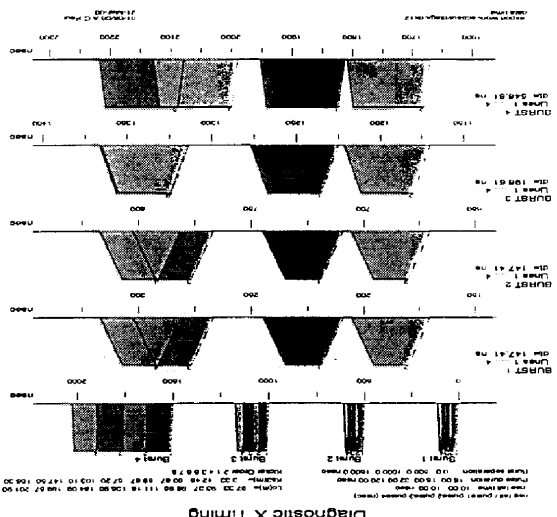
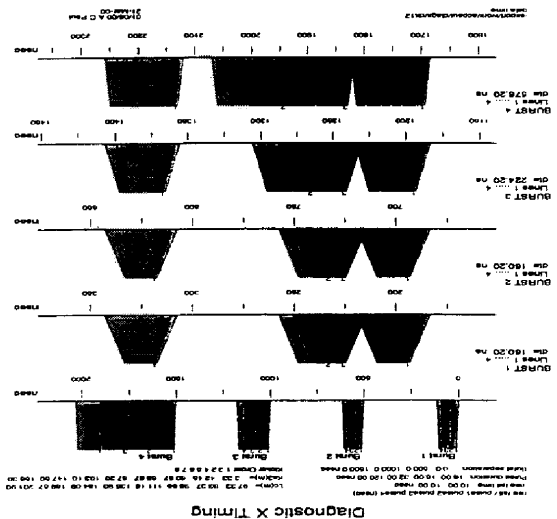
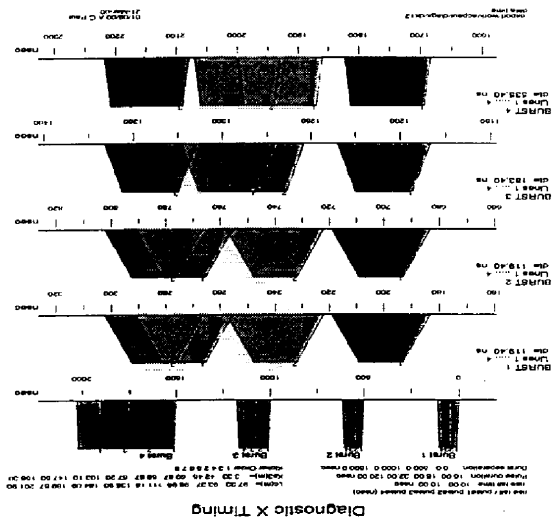
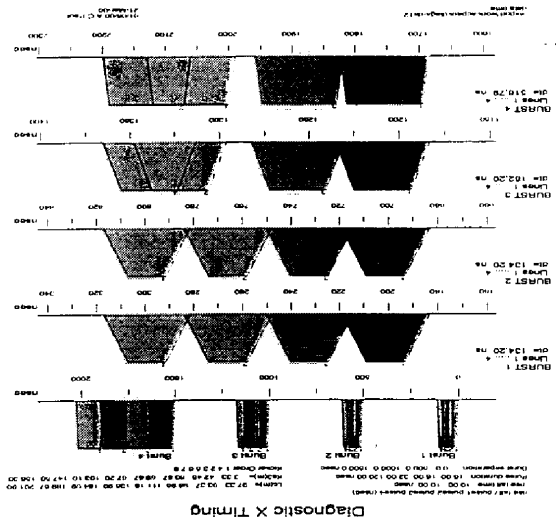
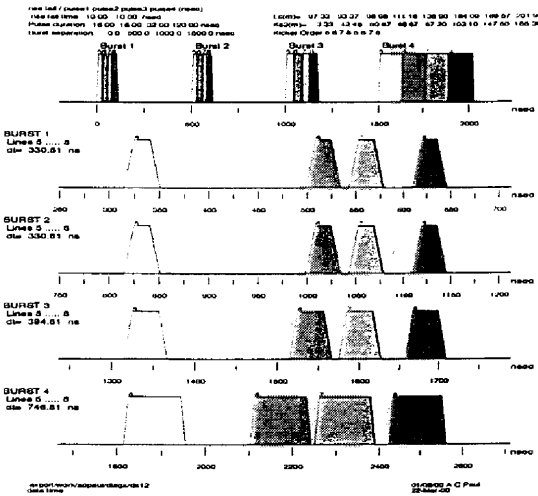
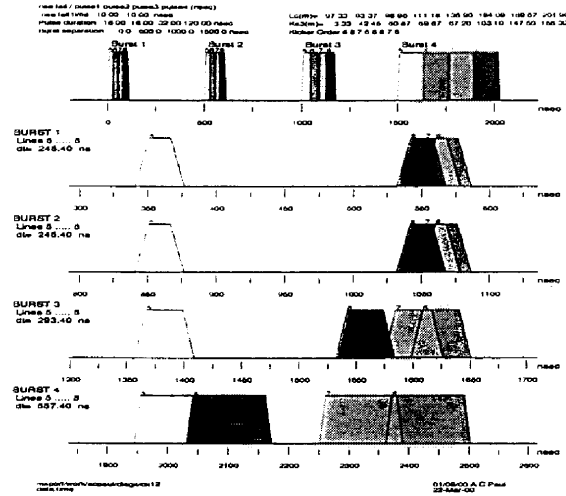


Figure 27) Beamlines 5 through 8 can be switched in any one of $4!$ sequences. The arrival time of the four pulses at their respective targets is controlled by that sequence, the length and therefore the transite time of the lines, and the selected pulse length. These 24 sequences are shown on the following four pages, six sequences per page in the order given in table 32, along with the time span for that sequence. The minimum time is for sequence 8 7 6 5.

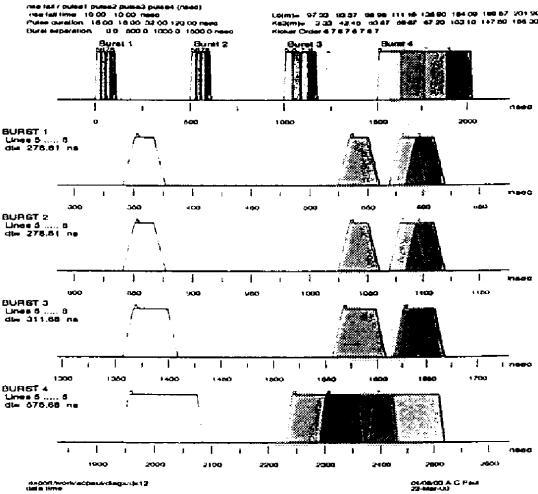
Diagnostic X Timing



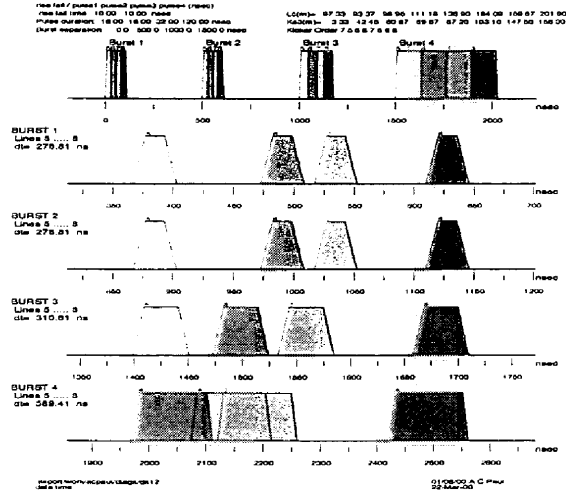
Diagnostic X Timing



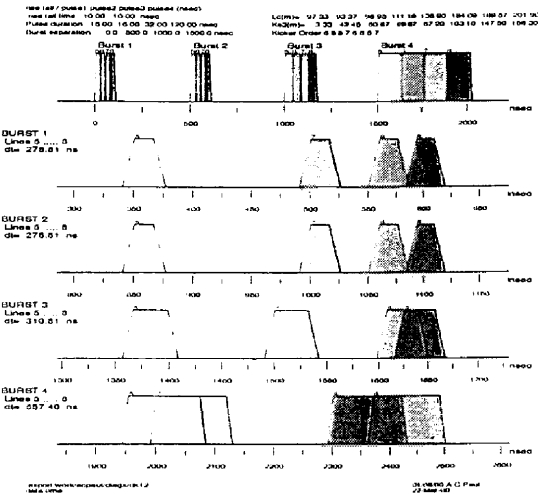
Diagnostic X Timing



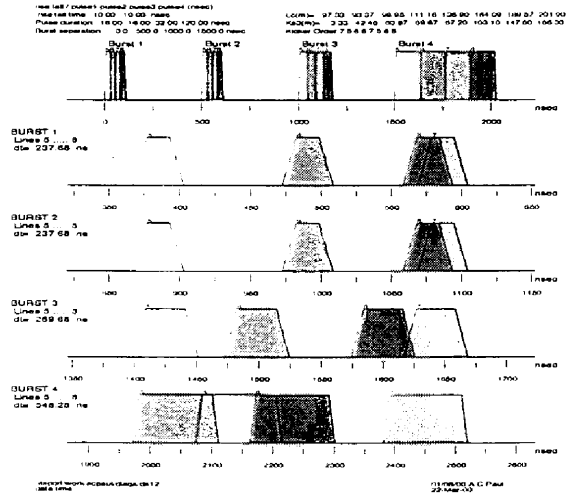
Diagnostic X Timing



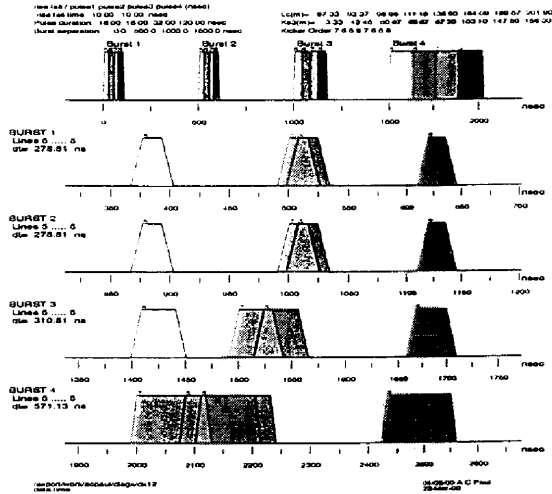
Diagnostic X Timing



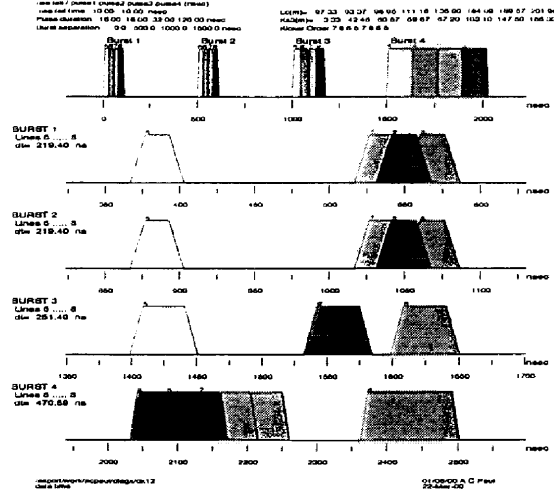
Diagnostic X Timing



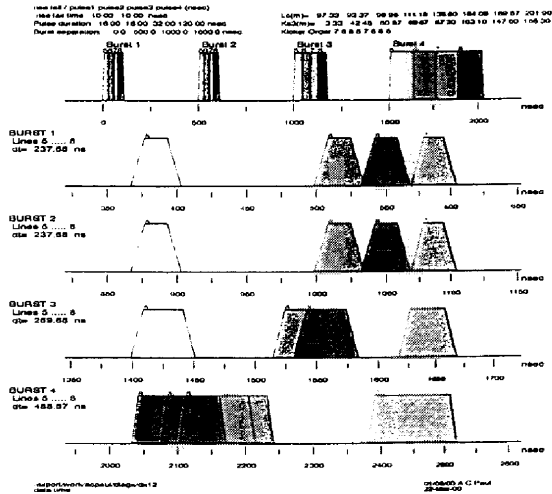
Diagnostic X Timing



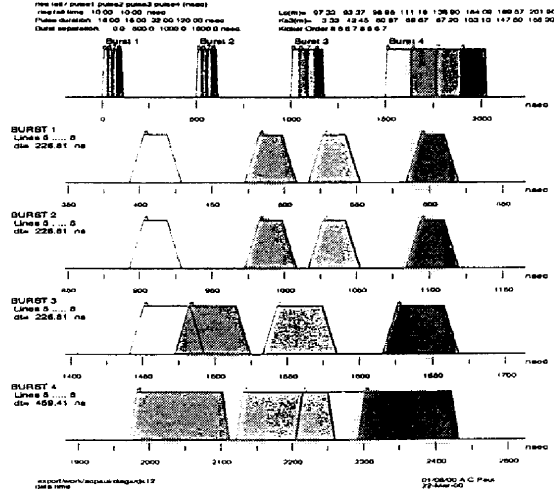
Diagnostic X Timing



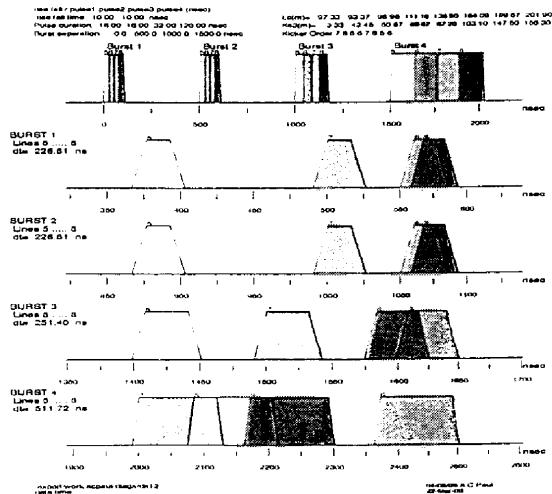
Diagnostic X Timing



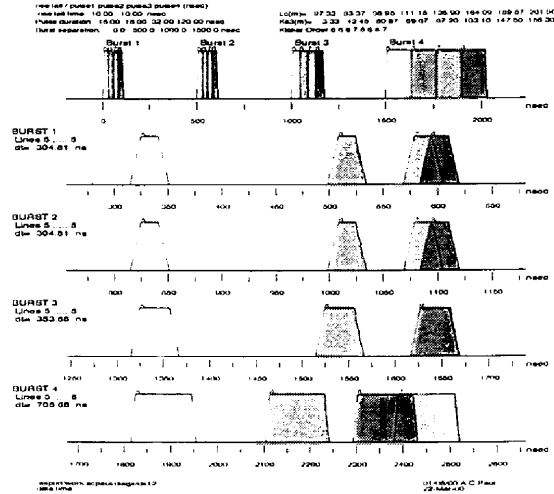
Diagnostic X Timing



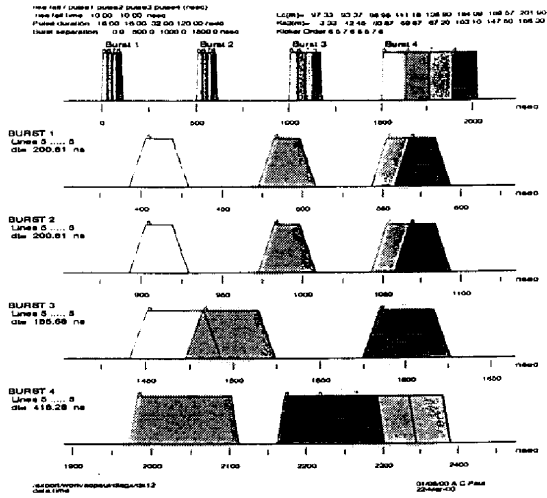
Diagnostic X Timing



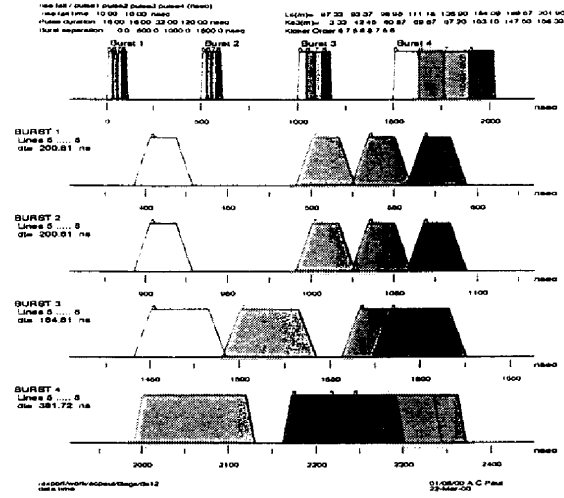
Diagnostic X Timing



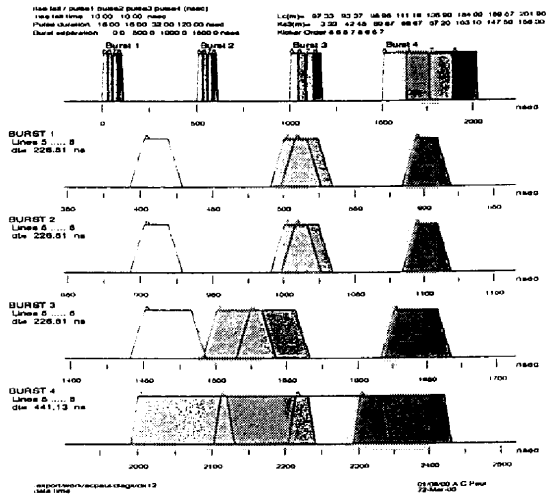
Diagnostic X Timing



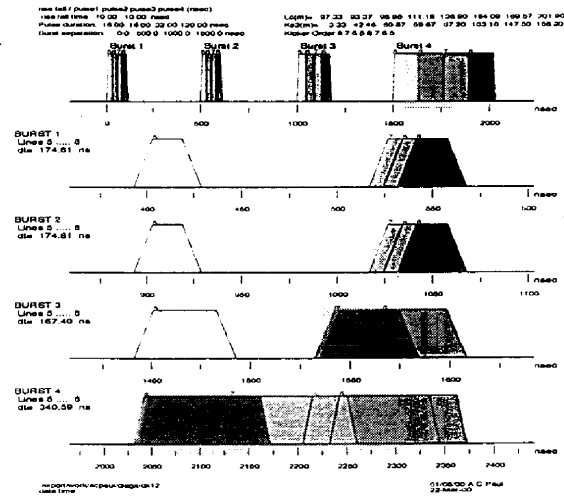
Diagnostic X Timing



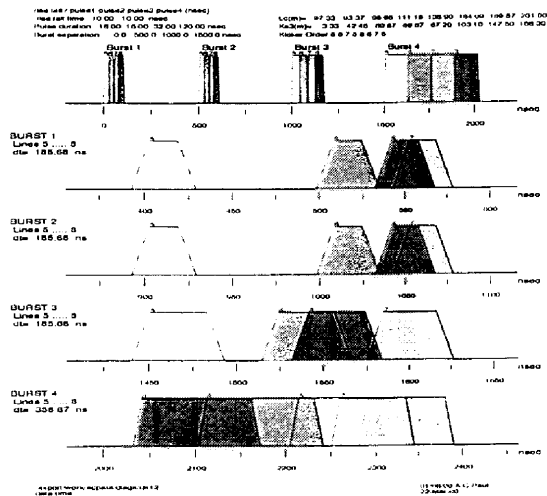
Diagnostic X Timing



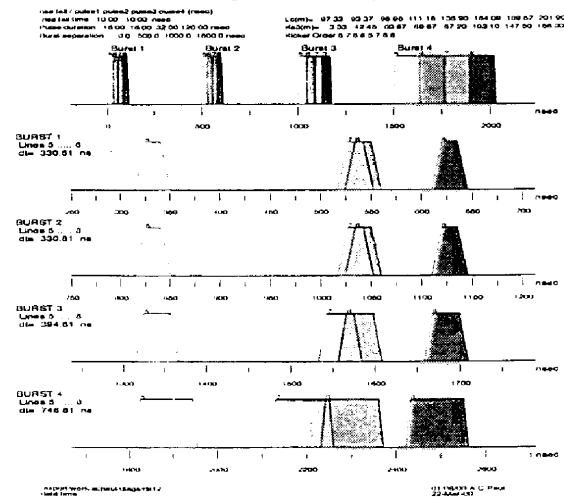
Diagnostic X Timing



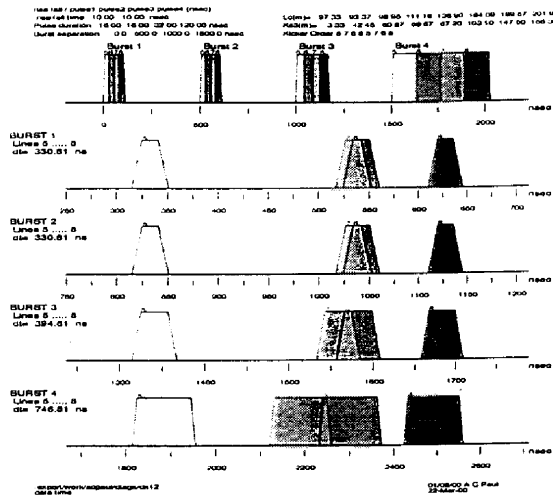
Diagnostic X Timing



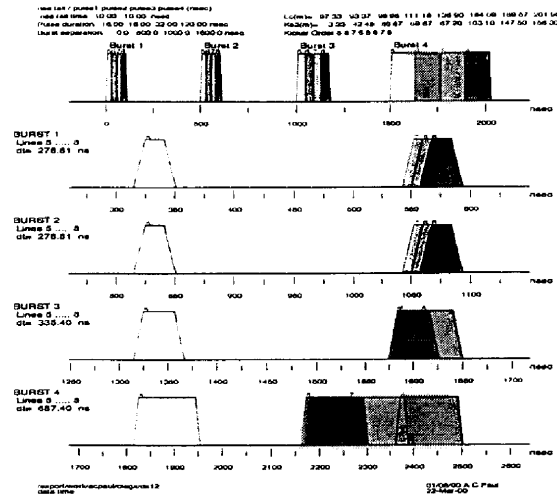
Diagnostic X Timing



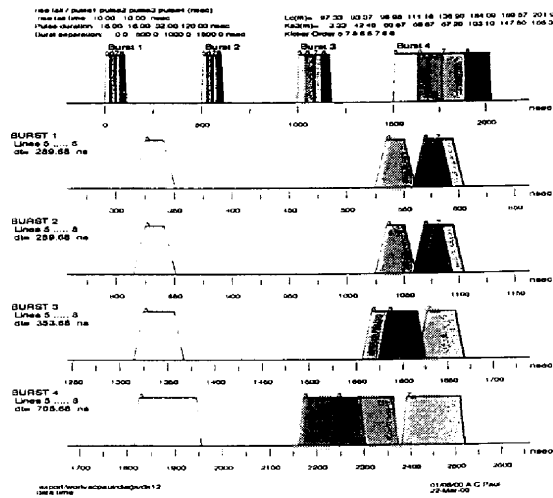
Diagnostic X Timing



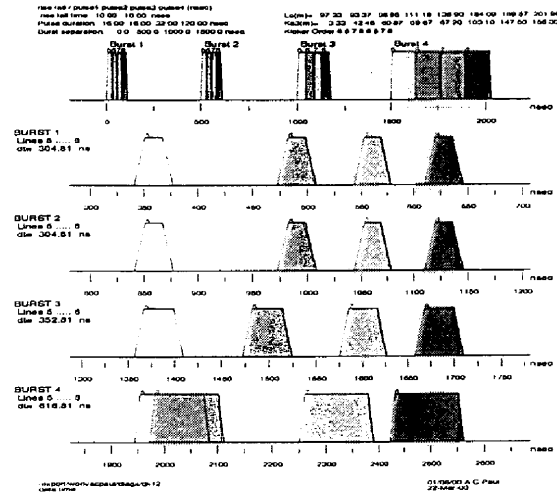
Diagnostic X Timing



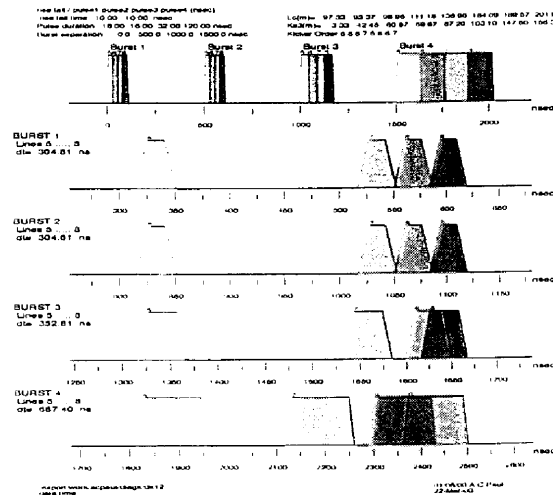
Diagnostic X Timing



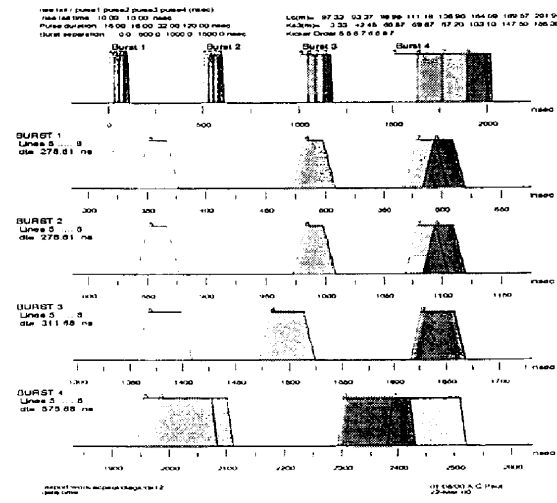
Diagnostic X Timing



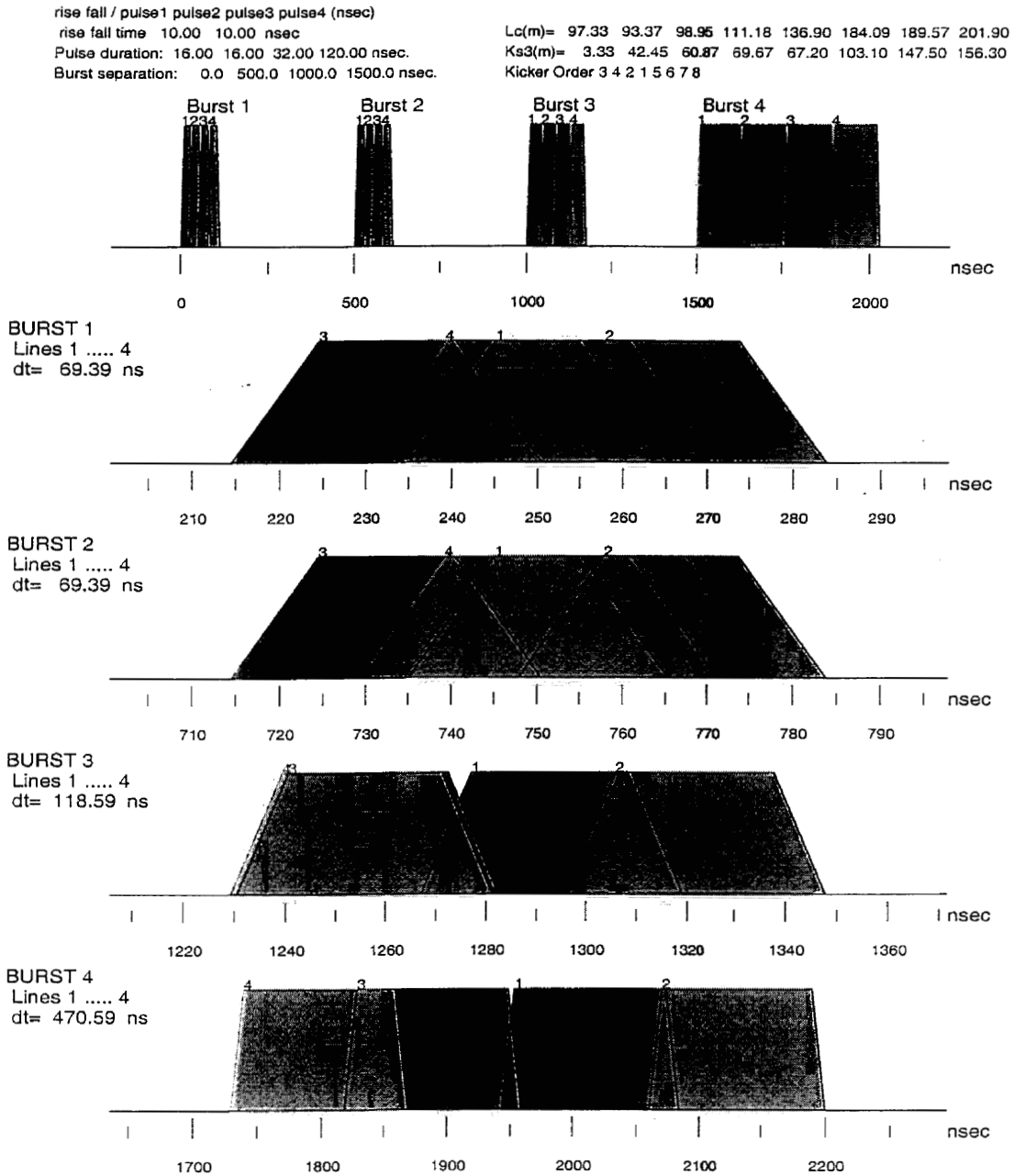
Diagnostic X Timing



Diagnostic X Timing



Diagnostic X Timing

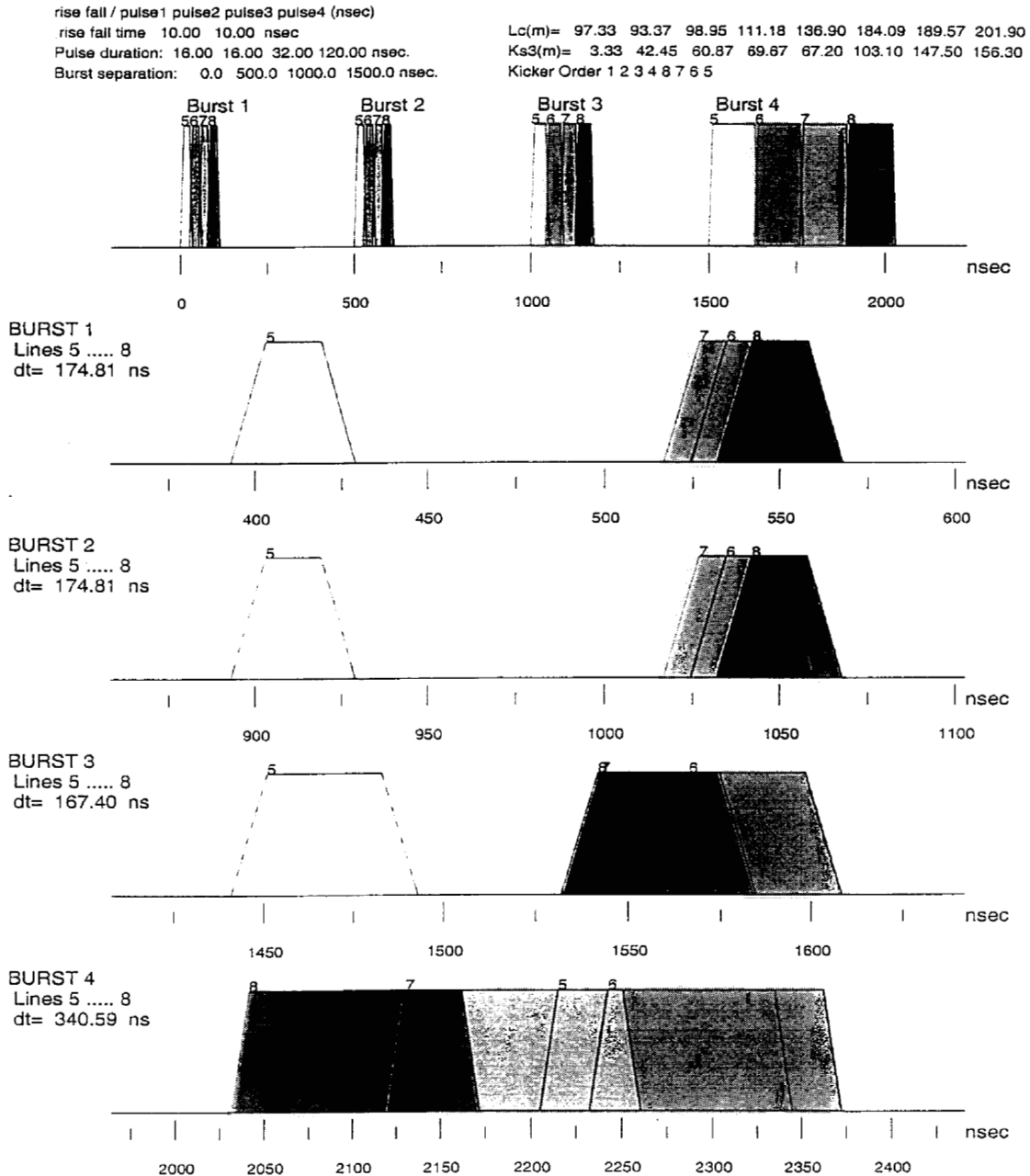


/export/work/acpaul/diag/dx12
 data.time

01/08/00 A.C.Paul
 5-Apr-00

Figure 28) Timing beamlines 1 through 4 fired in sequence 3421. A) division of the 2usec accelerator pulse.
 B) arrival time profile for burst 1. C) arrival time profile for burst 2.
 c) arrival time profile for burst 3. D) arrival time profile for burst 4.

Diagnostic X Timing



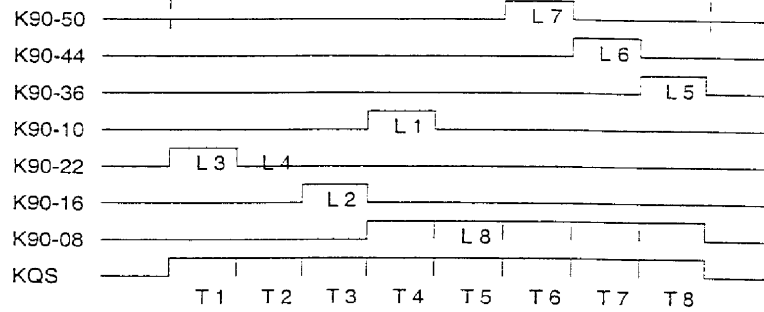
/export/work/acpaul/diagx/dx12
 data.time

01/08/00 A.C.Paul
 5-Apr-00

Figure 29) Timing beamlines 5 through 8 fired in sequence 8765. A) division of the 2usec accelerator pulse. B) arrival time profile for burst 1. C) arrival time profile for burst 2. c) arrival time profile for burst 3. D) arrival time profile for burst 4.

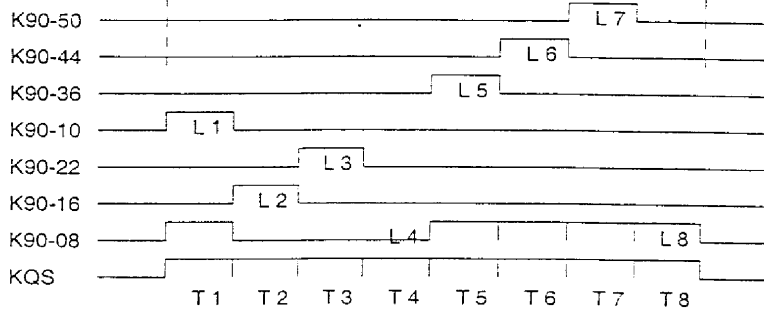
Diagnostic X Kicker Sequences

Firing sequence
3 4 2 1 8 7 6 5

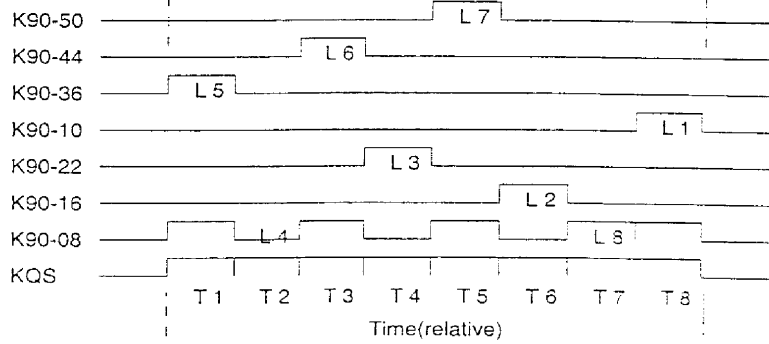


Firing sequence
1 2 3 4 5 6 7 8

Kicker



Firing sequence
5 4 6 3 7 2 8 1



/export/work/acpaul/diag/dx12
data_kt3

5-Apr-00

A.O. Paul
5-Apr-00

Figure 30) Kicker firing sequences for A) minimum arrival times at the firing point, B) numerically sequential order, and C) sequences giving maximum number of septum transversals.

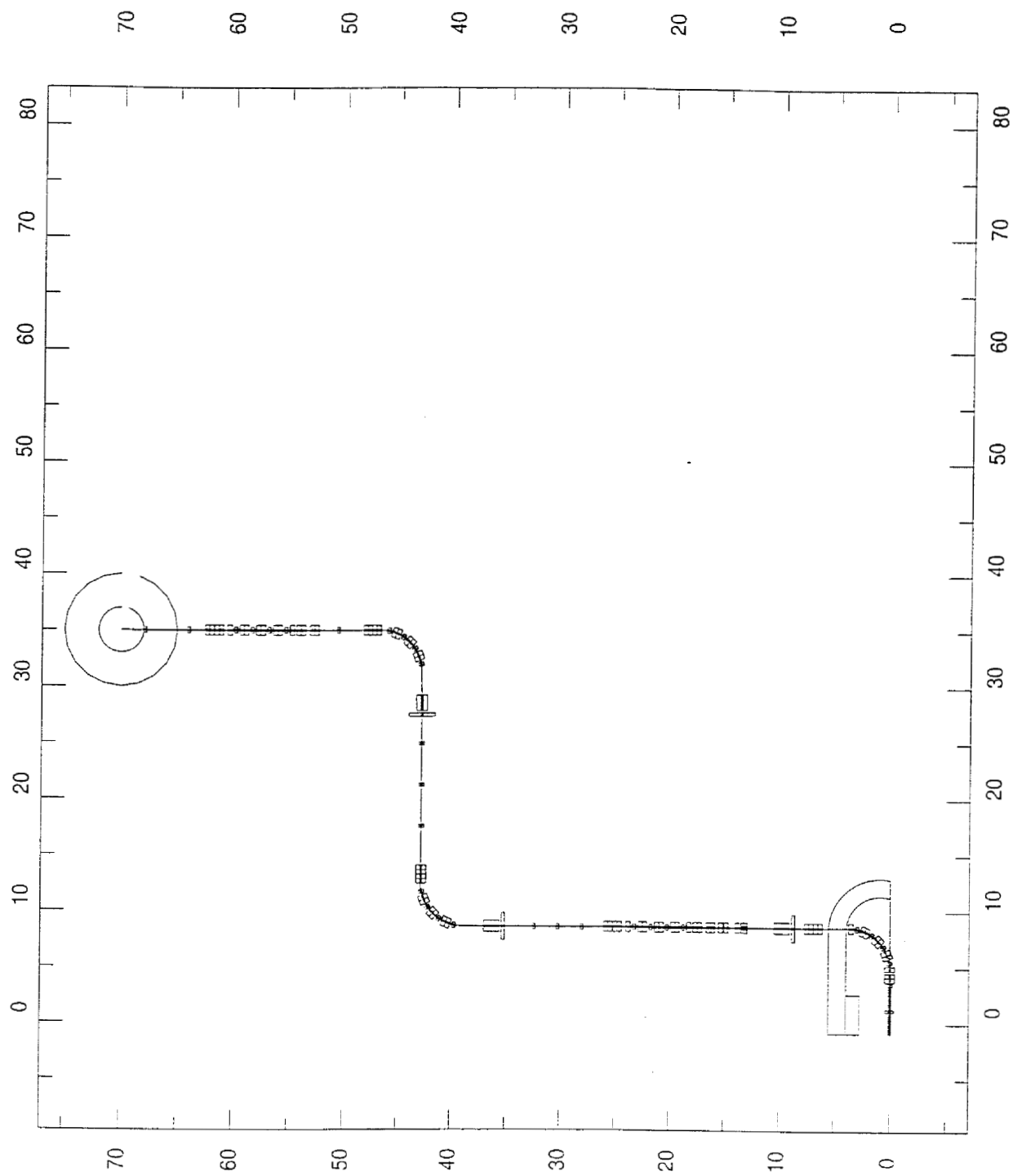


Figure 31) Beamline 1 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point.
The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

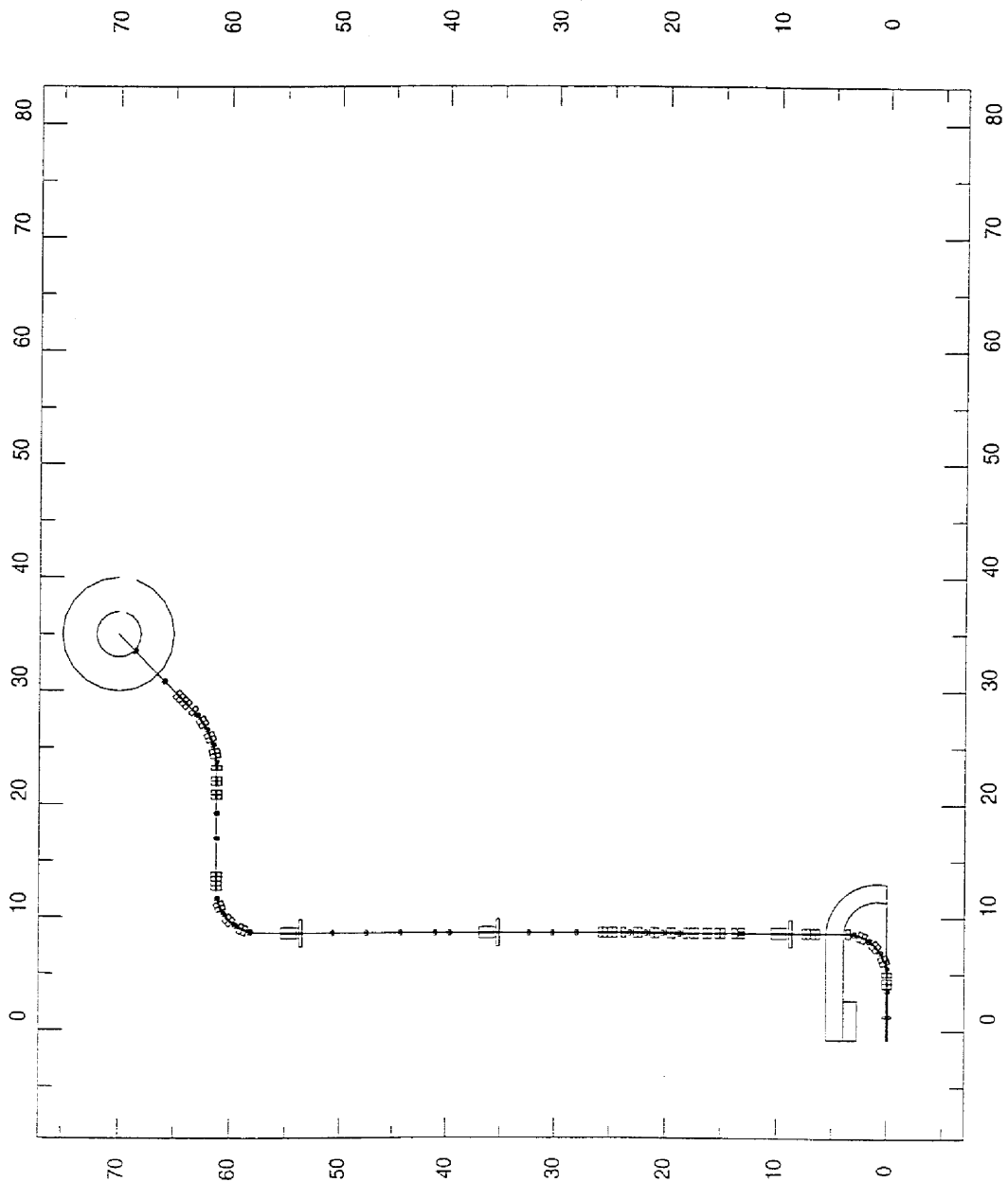


Figure 34) Beamline 2 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point.
The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

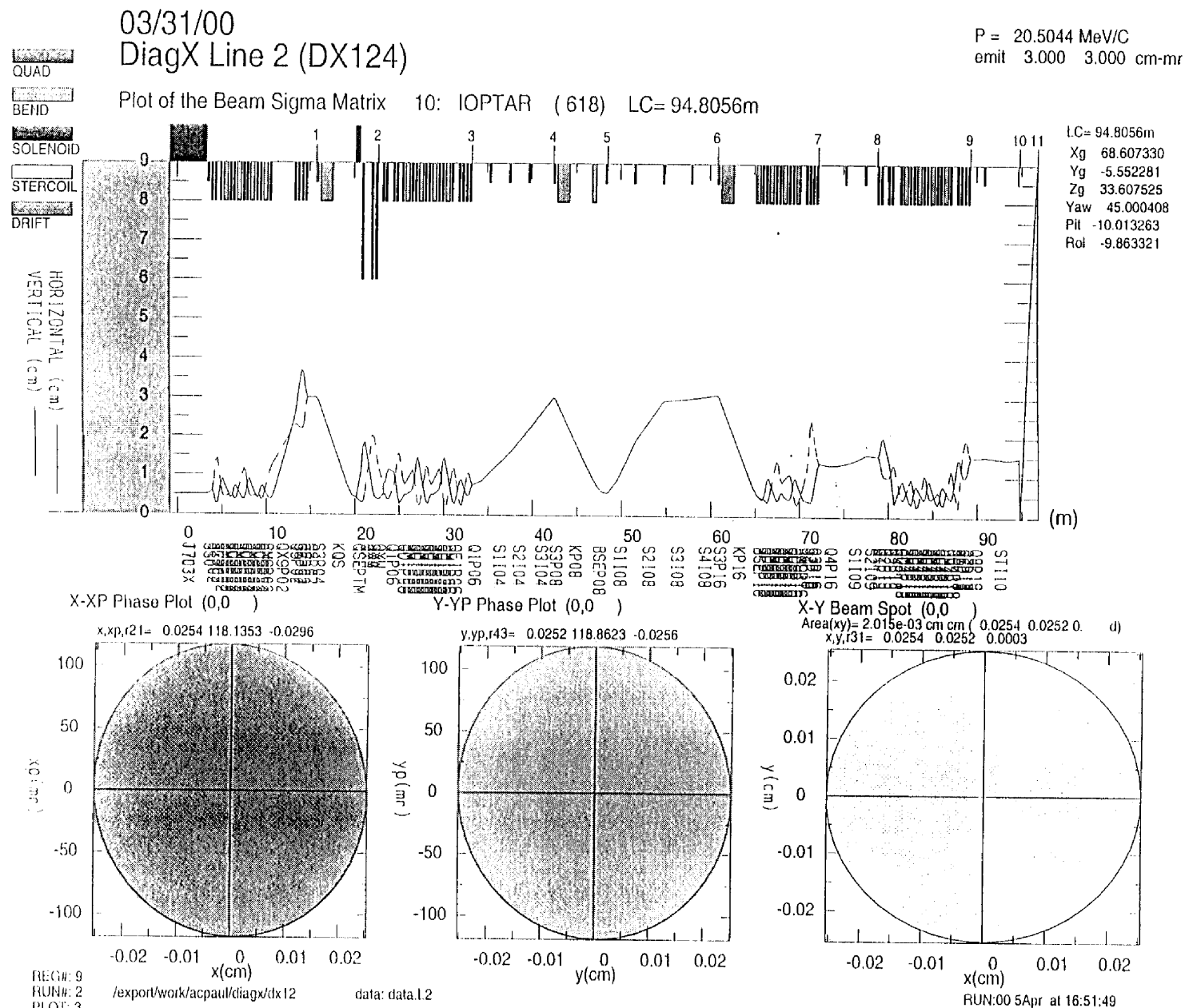
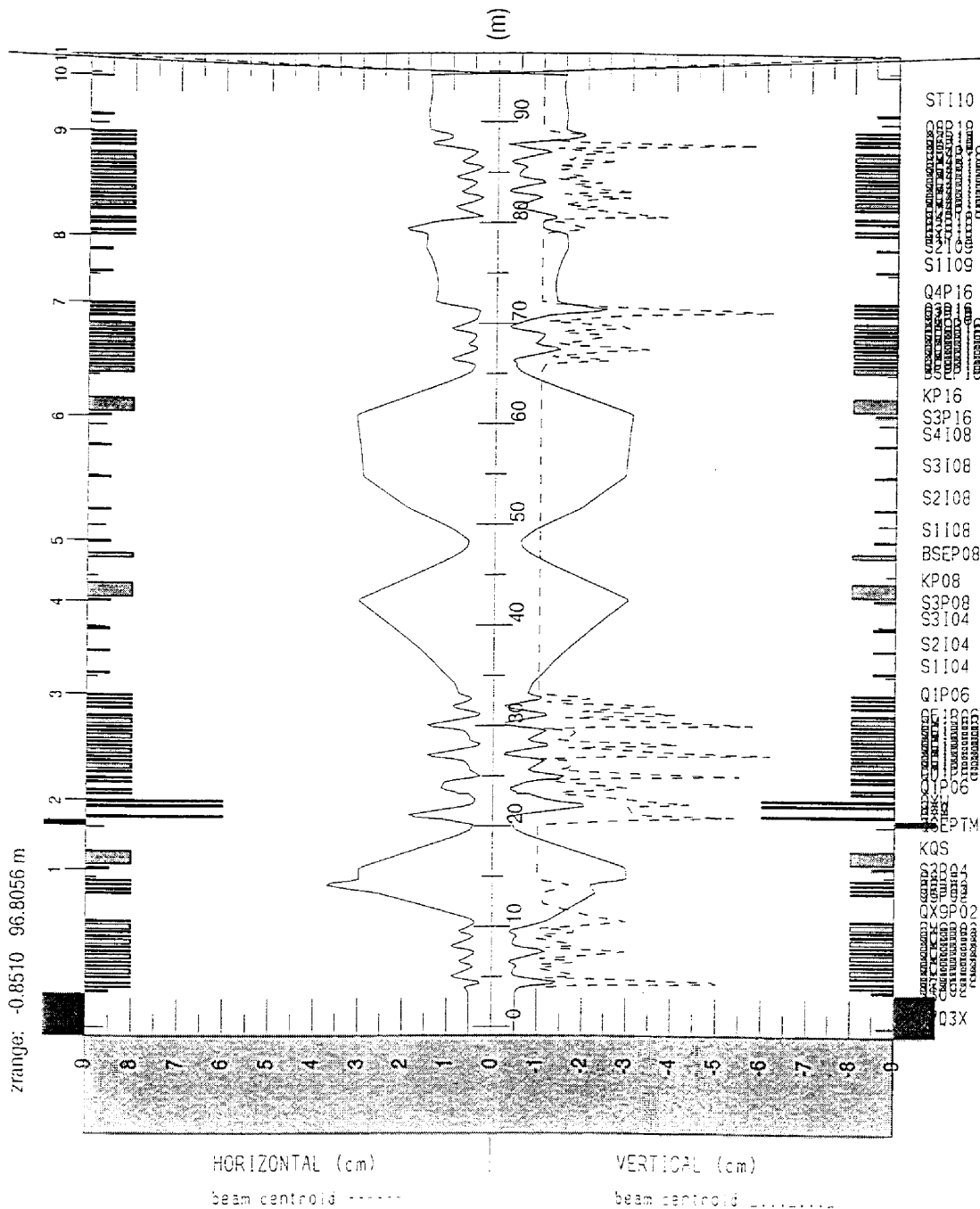


Figure 35) Beamline 2 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round, $x=y=r$.

The beam phase space and spot size at the X-ray converter target located at IO location 11 is also shown. IO 11 is indicated at the top of the envelope plot. The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin, IO location 11.

P = 20.5044 MeV/C
emit 3.000 3.000 cm-nnr

QUAD
BEND
SOLENOID
STERCOIL
DRIFT



```

REG# : 9
RUN# : 2
PLOT : 4
/export/work/acpaul/tlax/tlx12
data_data.L2
Flutter 6.213
RUN:00 5Apr at 16:51:49

```

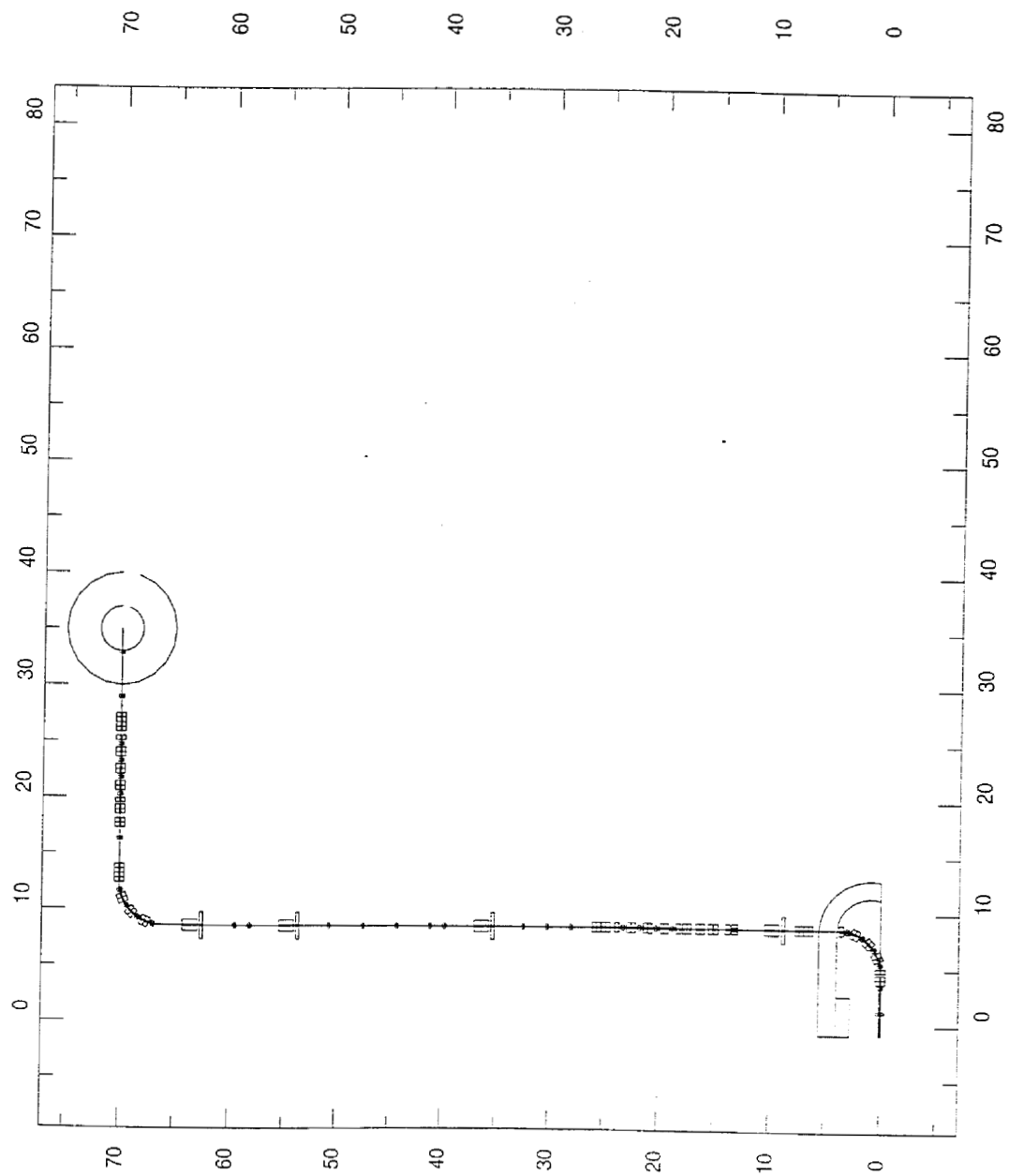


Figure 37) Beamline 3 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point.
The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

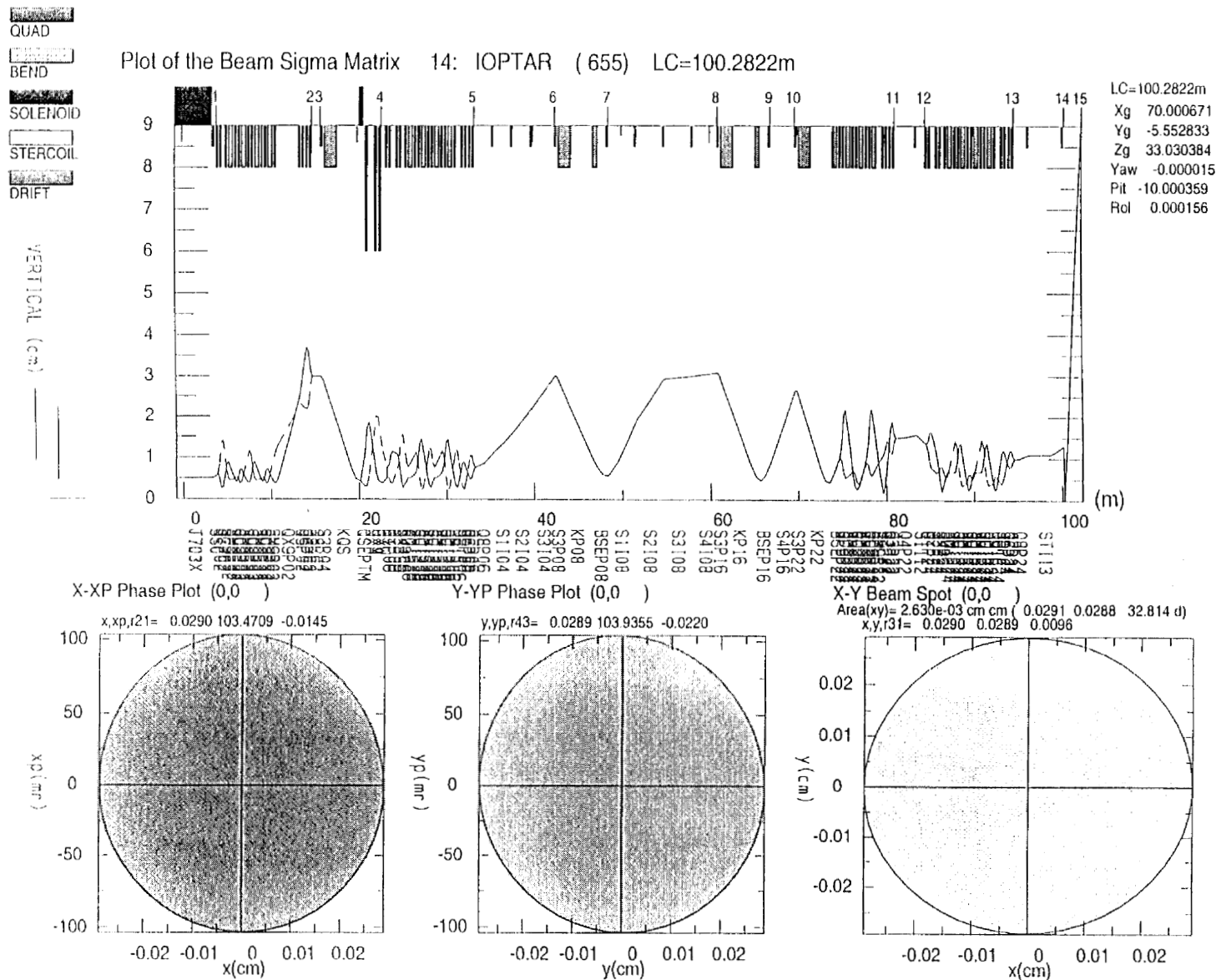


Figure 38) Beamline 3 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round, $x=y=r$.

The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.

The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin, IO location 15.

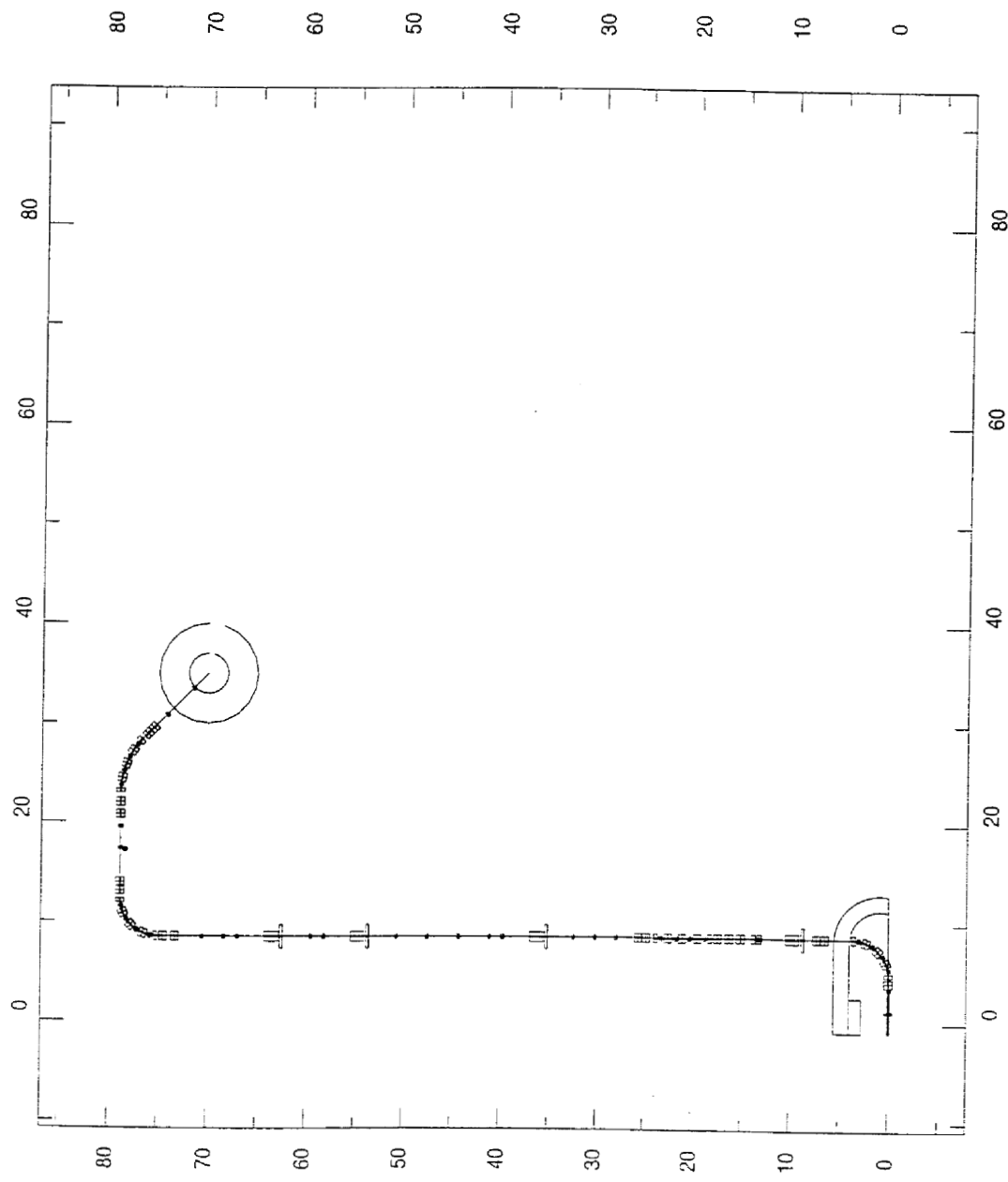


Figure 40) Beamline 4 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point.
The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

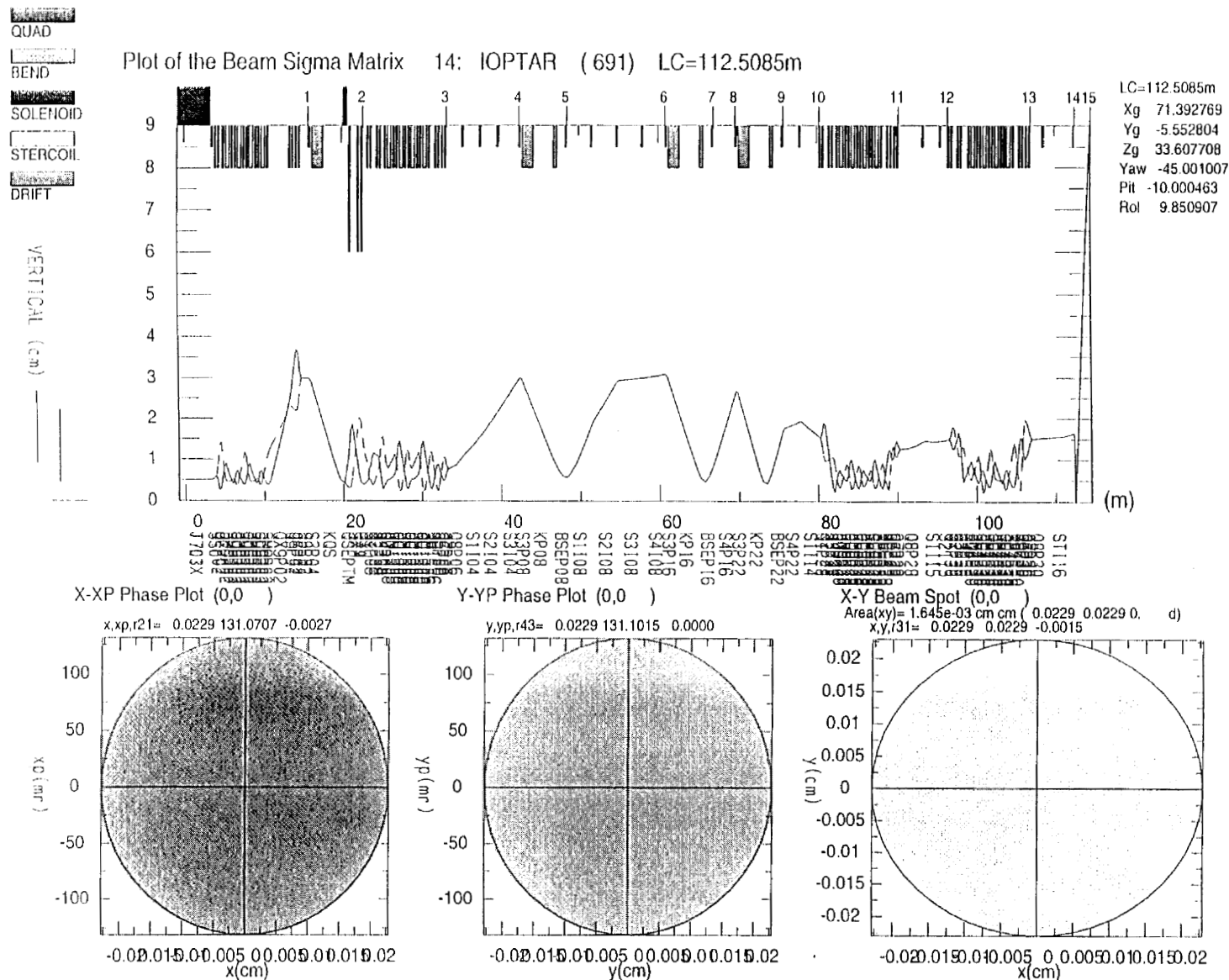


Figure 41) Beamline 4 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round, $x=y=r$.

The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.

The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin, IO location 15.

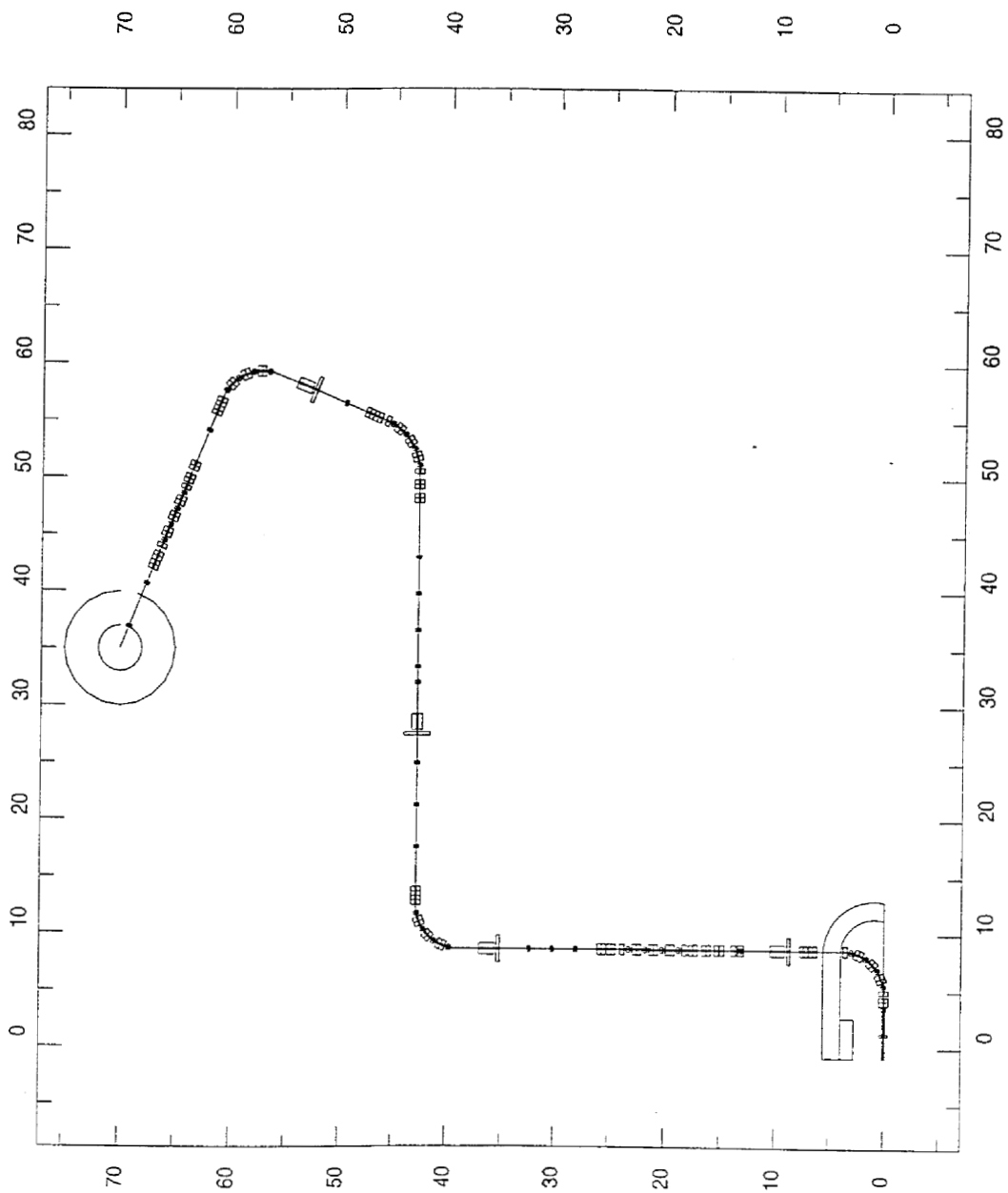


Figure 43) Beamline 5 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point.
The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

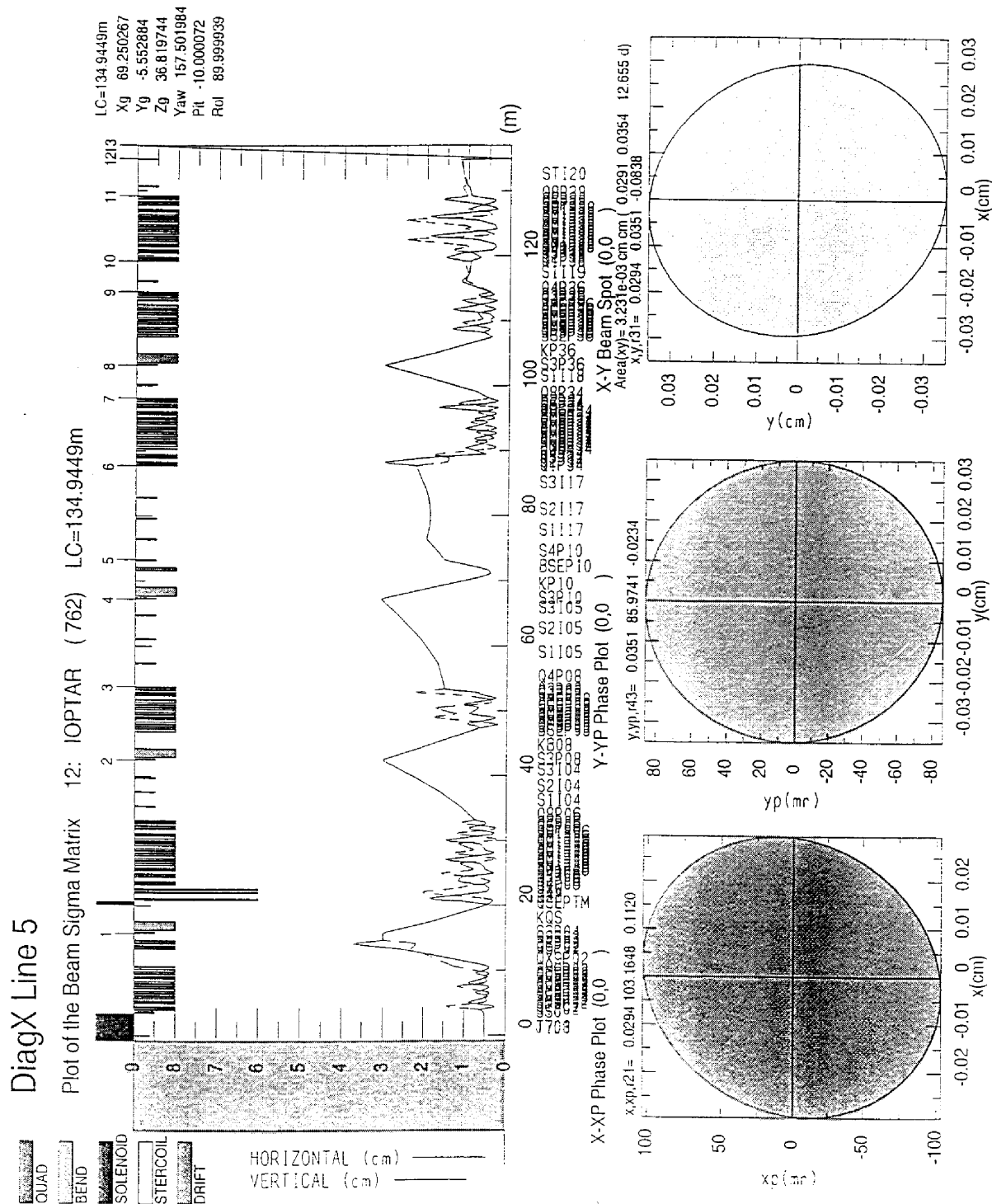


Figure 4-4) Beamline 5 showing the horizontal and vertical beams overlaid on the upper frame. Only one line is seen where the beam is round, $x=y=r$. The beam phase space and spot size at the X-ray converter target located at IO location 12 is also shown. IO 12 is indicated at the top of the envelope plot. The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin, IO location 13.

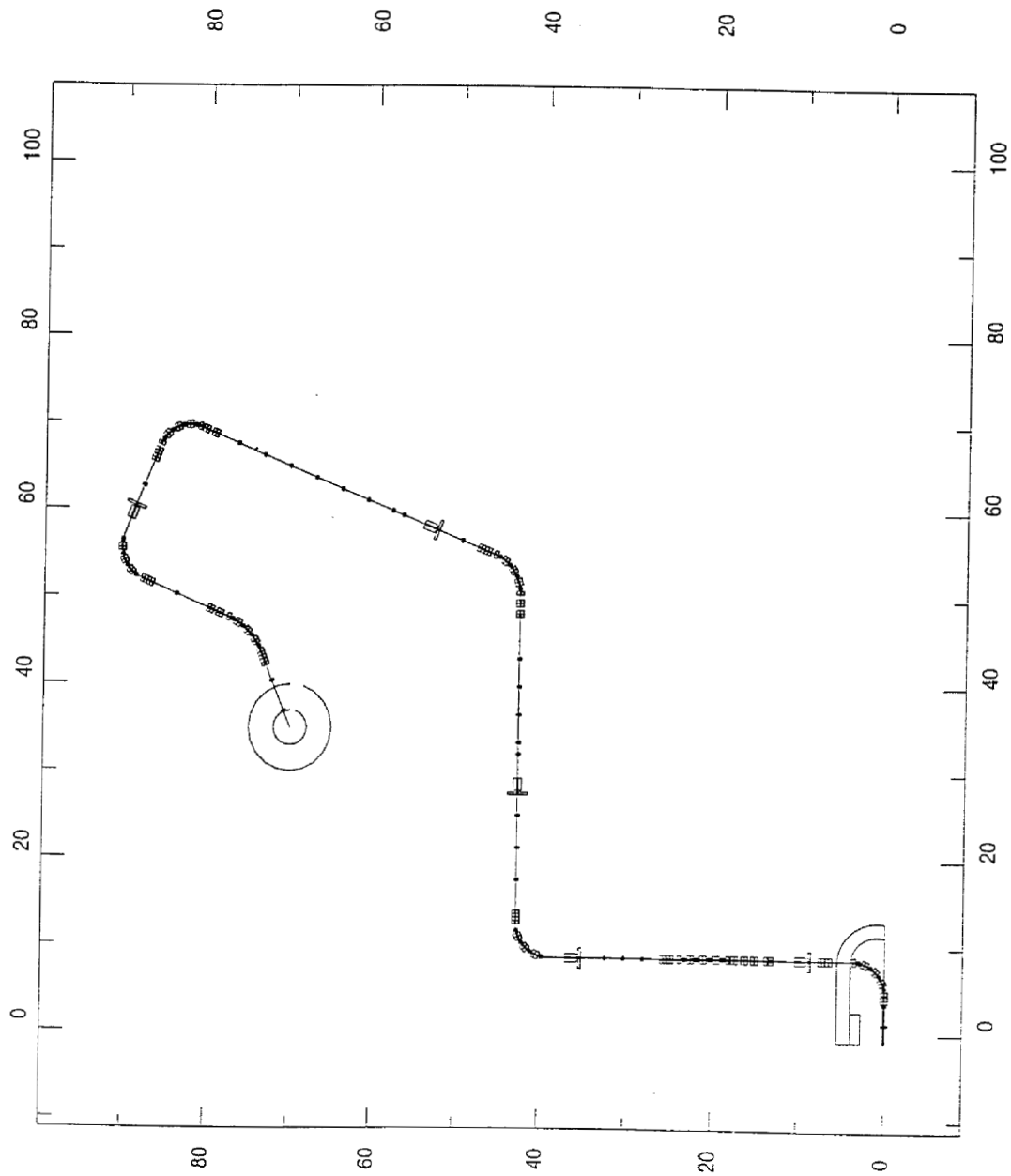


Figure 46) Beamline 6 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point. The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

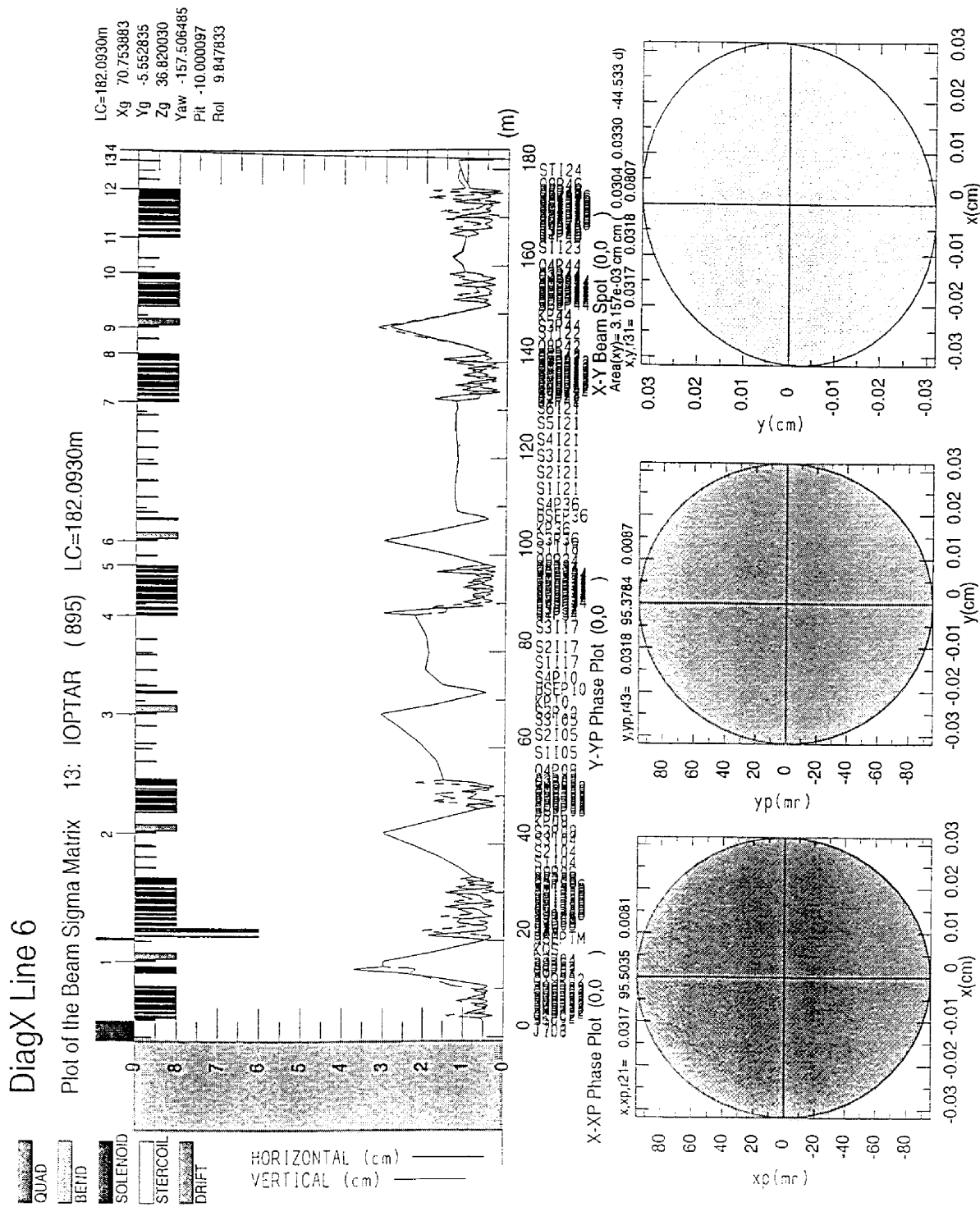


Figure 47) Beamline 6 showing the horizontal and vertical beams overlaid on the upper frame. Only one line is seen where the beam is round, $x=y=r$.

The beam phase space and spot size at the X-ray converter target located at IO location 13 is also shown. IO 14 is indicated at the top of the envelope plot.
 The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LNL origin, IO location 14.

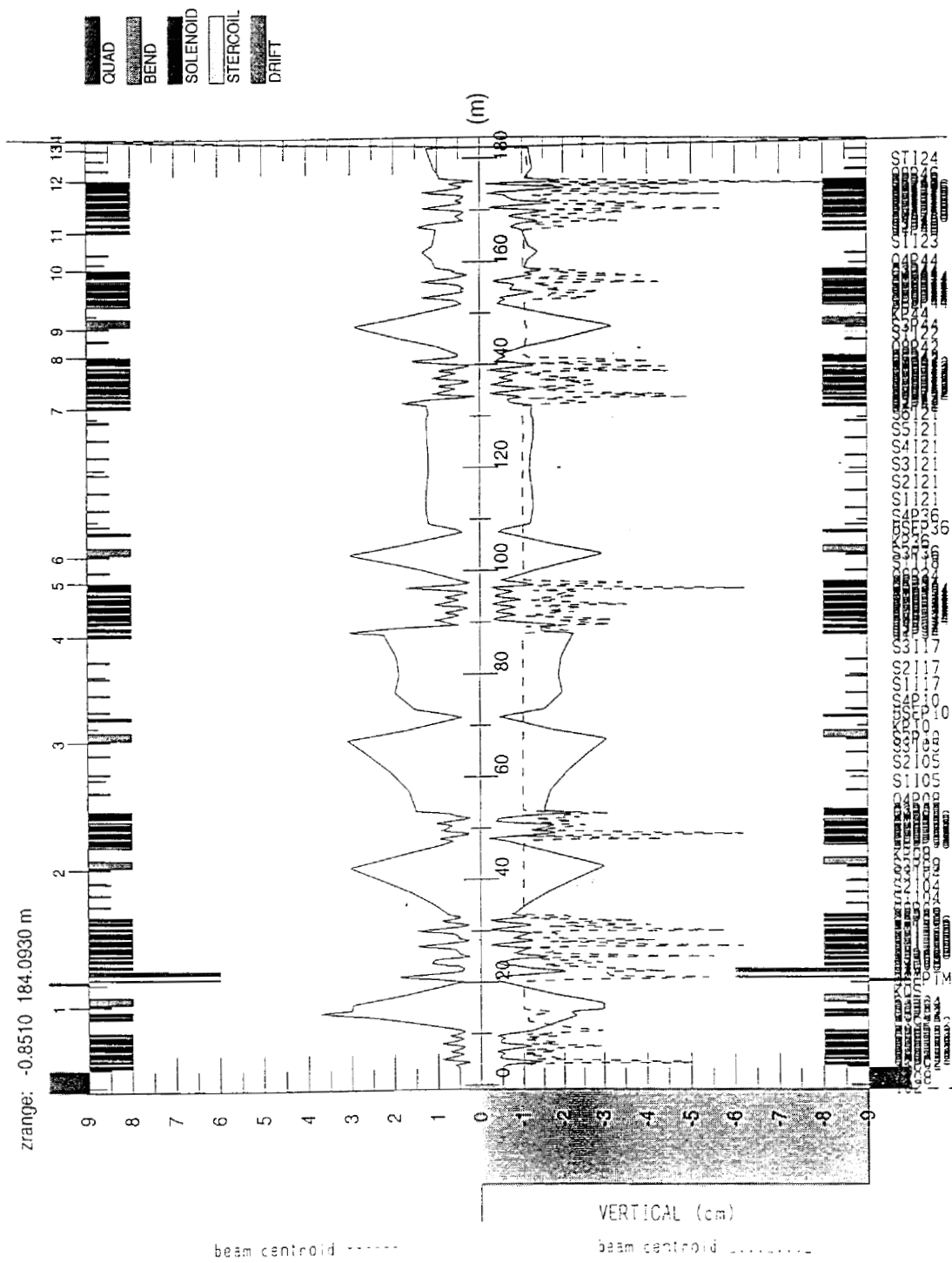


Figure -48) Beamline 6 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, maximum of X/Y or Y/X. Kicker K90p08 follows IO point 1, kicker K90p10 follows IO 2, kicker K90p36 follows IO 3, kicker K90p44 follows IO 9. The firing point is at IO 14.

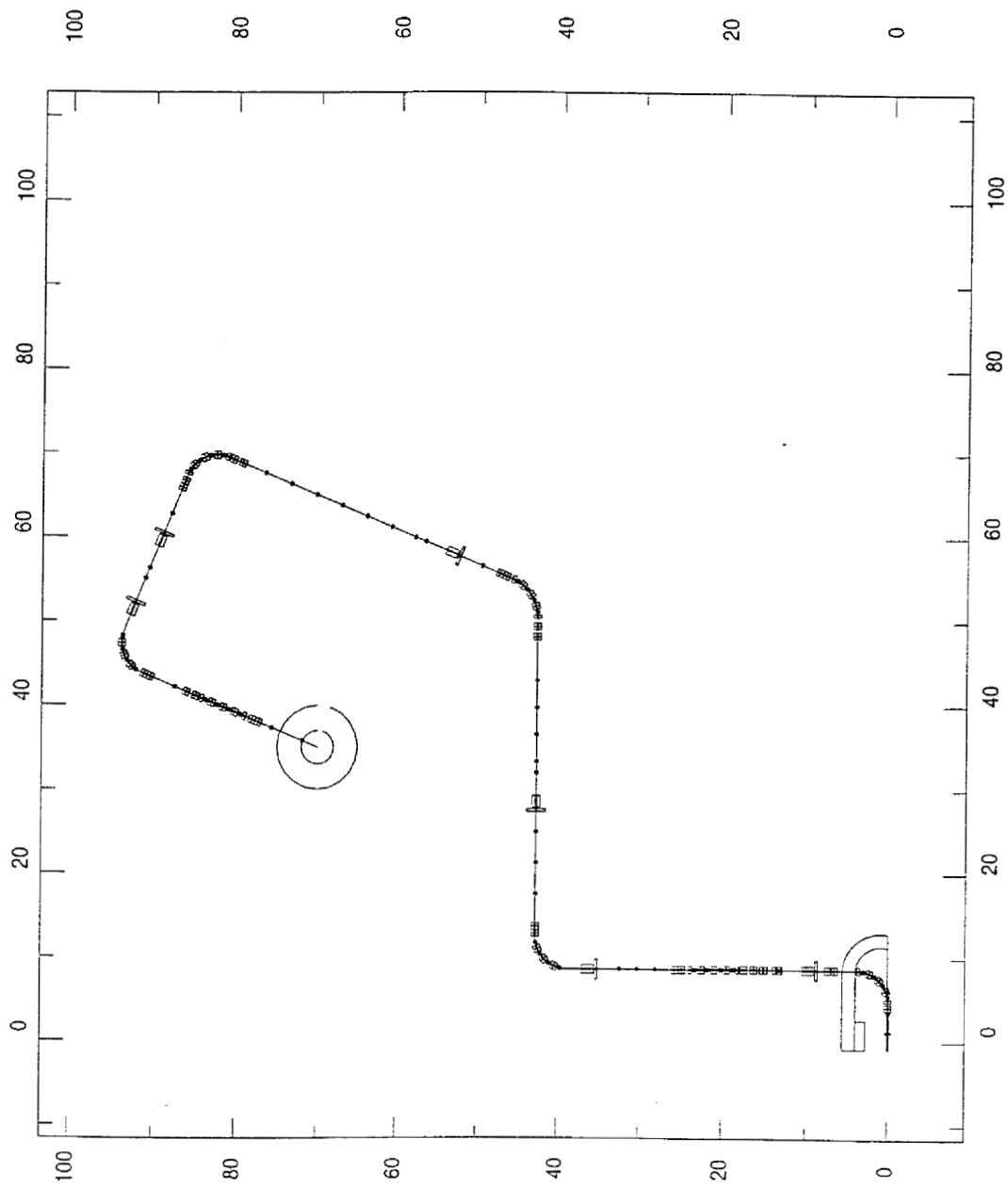


Figure 49) Beamline 7 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point. The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

Diagx Line 7

Plot of the Beam Sigma Matrix 15: IOPTAR (933) LC=187.5726m

LC=187.5726m
Xg 71.819778
Yg -5.553635
Zg 35.754063
Yaw -112.507179
Pit -10.000213
Rol -0.000254

QUAD
BEND
SOLENOID
STERCOIL
DRIPT

HORIZONTAL (cm)
VERTICAL (cm)

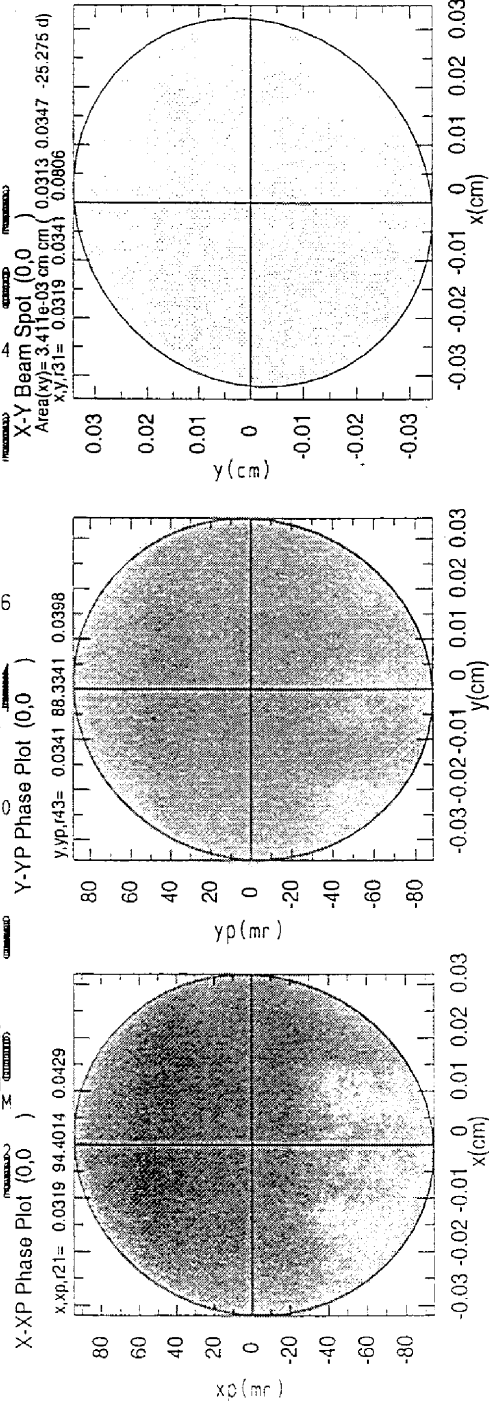
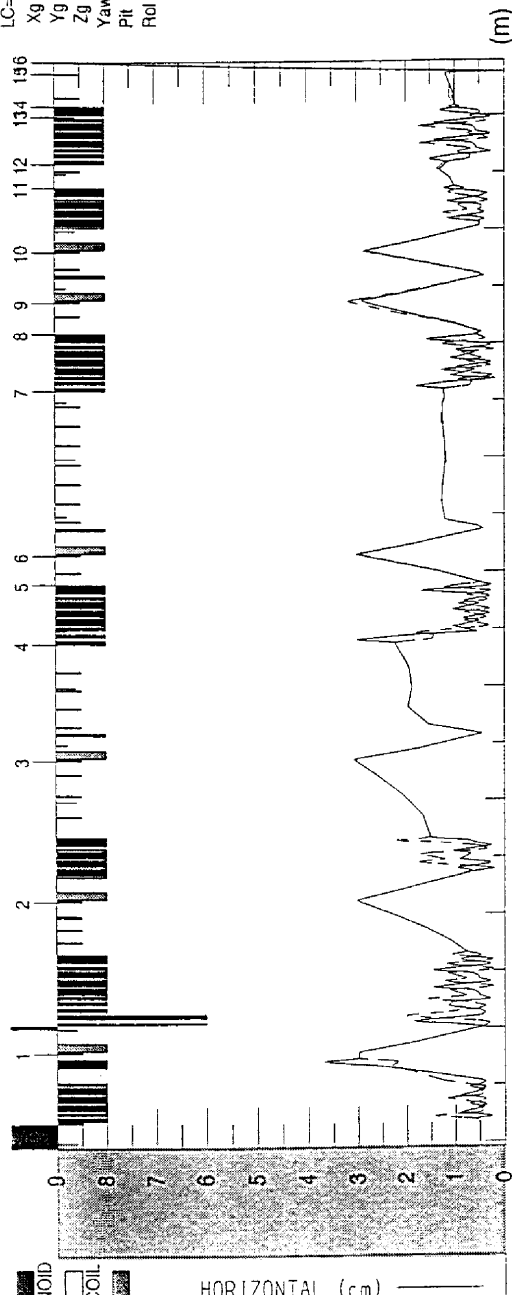


Figure 50) Beamline 7 showing the horizontal and vertical beams overlapped on the upper frame. Only one line is seen where the beam is round, $x=y=r$.

The beam phase space and spot size at the X-ray converter target located at IO location 14 is also shown. IO 14 is indicated at the top of the envelope plot.

The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin, IO location 16.

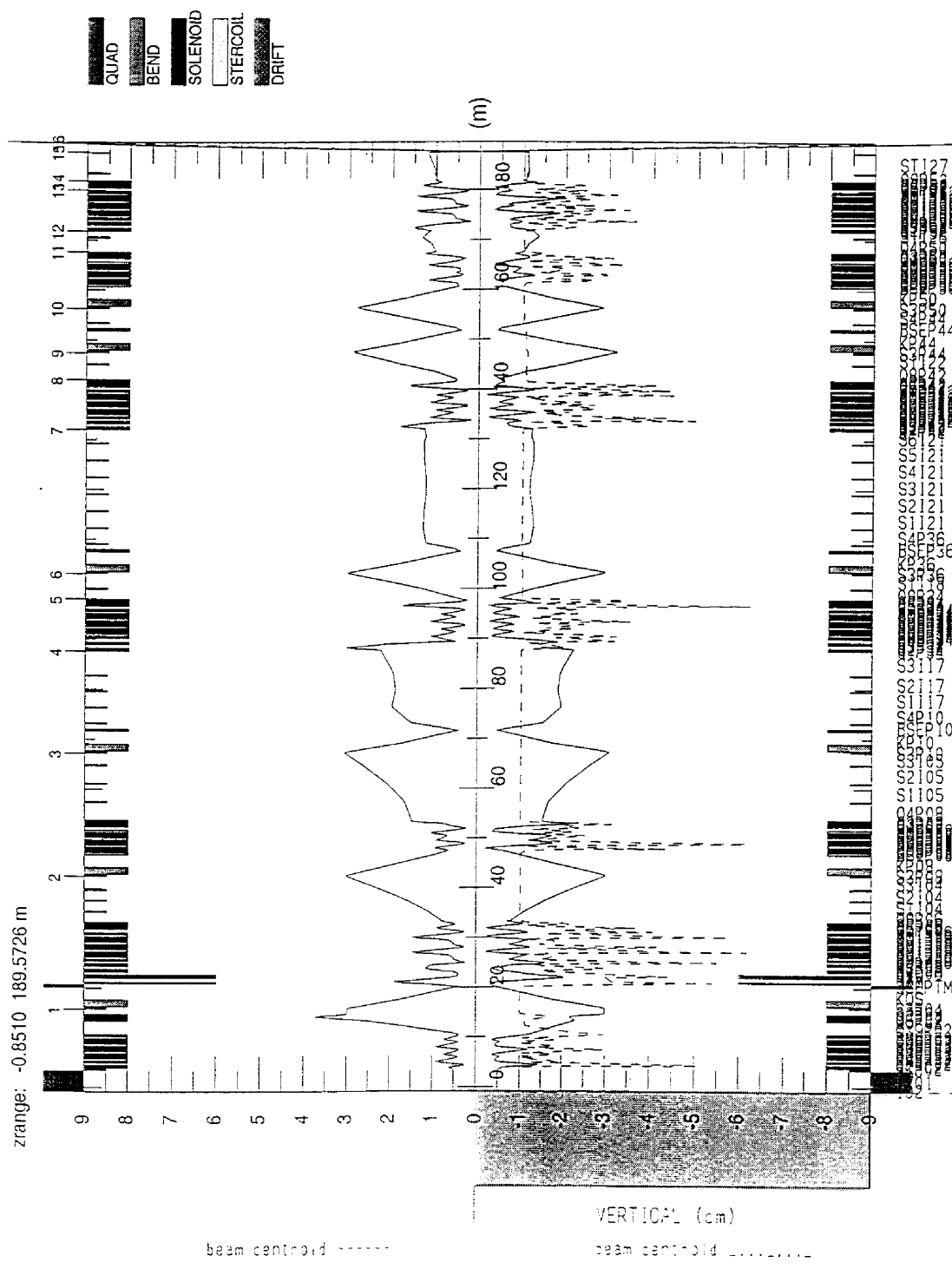


Figure 51) Beamline 7 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, maximum of X/Y or Y/X. Kicker KQS follows IO point 1, kicker K90p08 follows IO 2, kicker K90p10 follows IO 3, kicker K90p36 follows IO6. Kicker K90p44 follows IO 9, kicker K90p50 follows IO 10. The firing point is at IO 16.

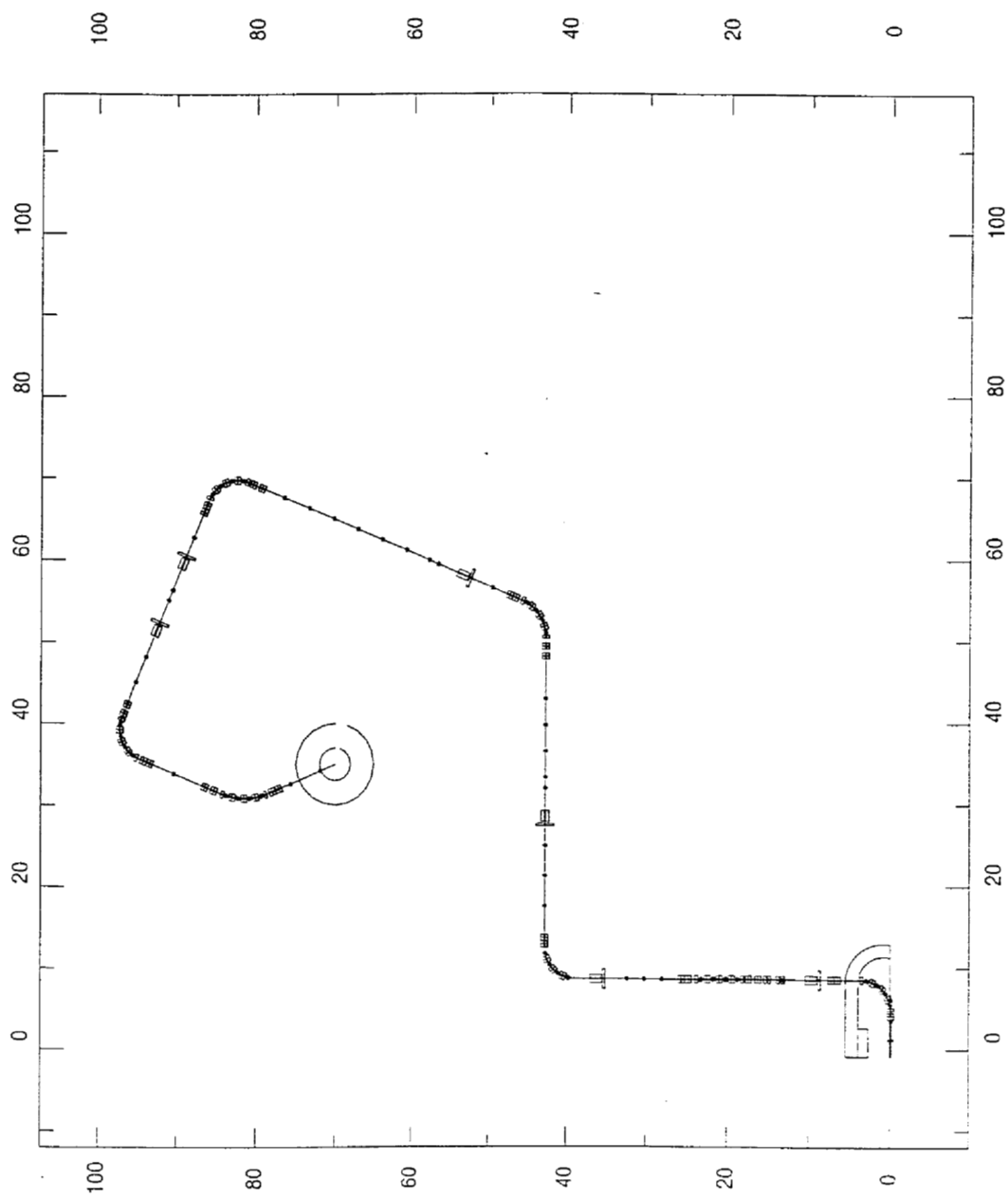


Figure 52) Beamline 8 geometry plot from the exit of the accelerator to the firing point. Circles of 2 and 5 meter radius are shown at the firing point.

The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin.

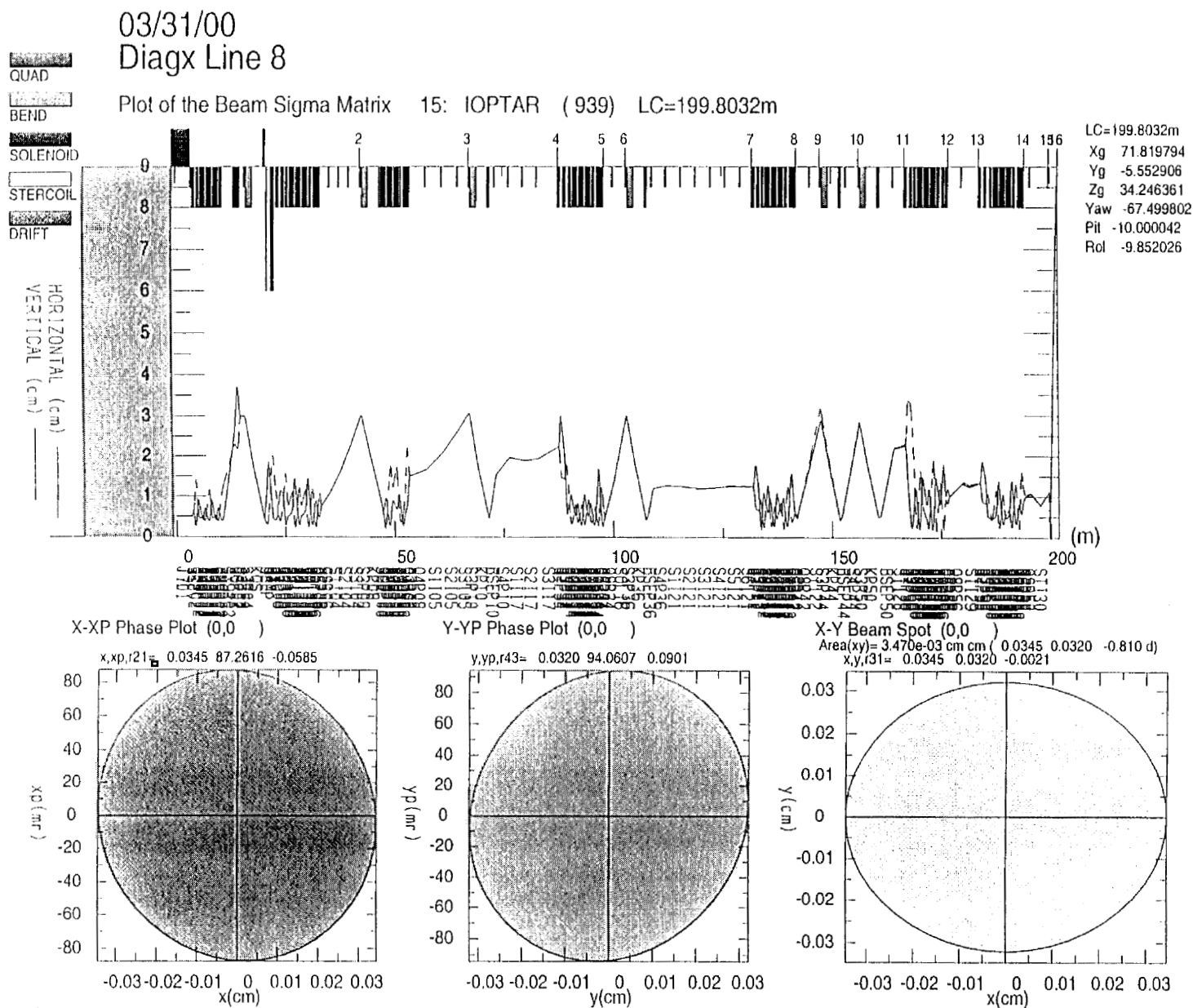


Figure 53) Beamline 8 showing the horizontal and vertical beams overplotted on the upper frame. Only one line is seen where the beam is round, $x=y=r$.

The beam phase space and spot size at the X-ray converter target located at IO location 15 is also shown. IO 15 is indicated at the top of the envelope plot.

The firing point is located at global coordinates (35.0, 70.0, -5.90) meters from the LLNL origin, IO location 16.

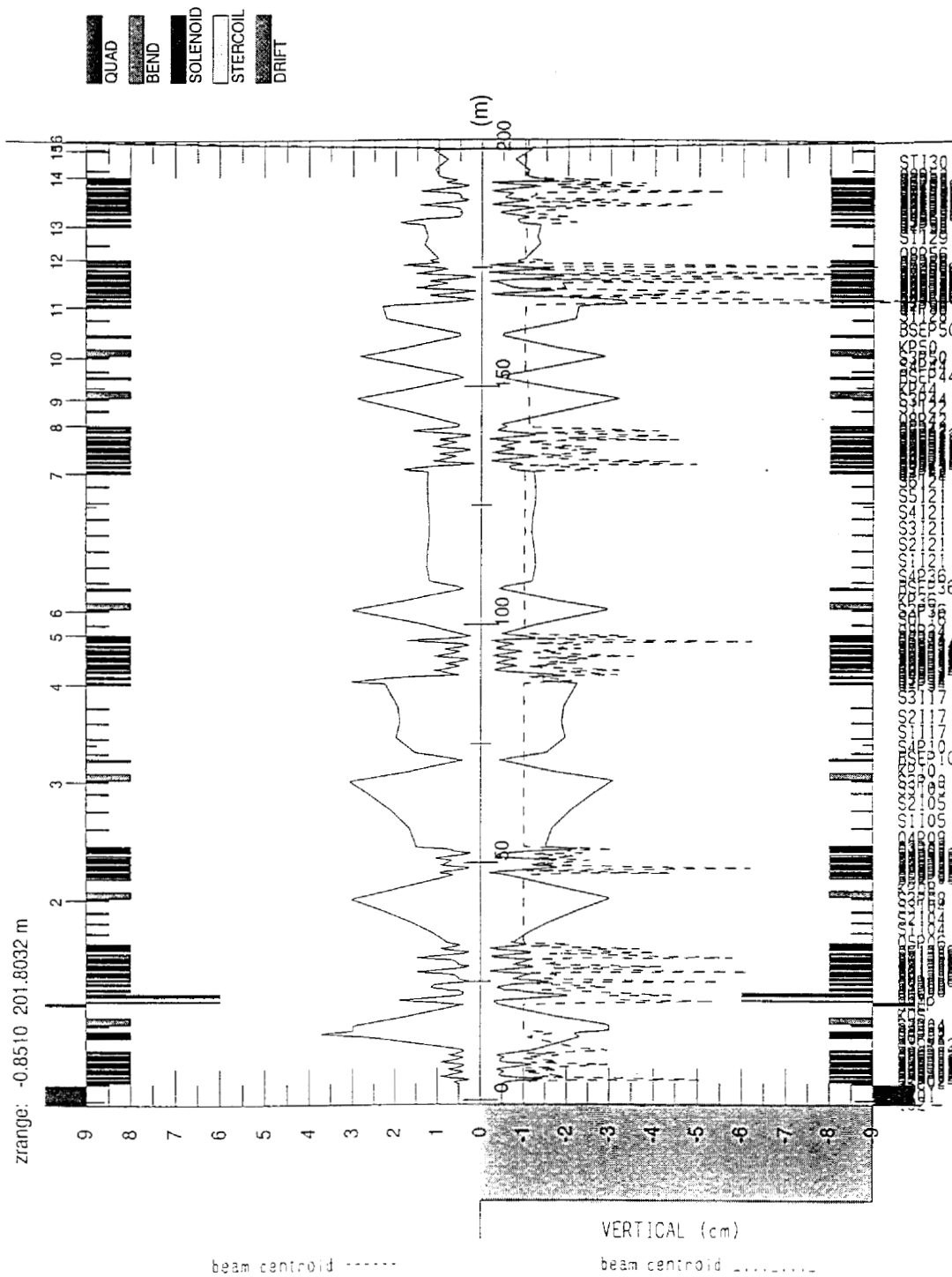


Figure 54) Beamline 8 plot with horizontal beam above and vertical beam below. Dashed curve is the beam flutter, maximum of X/Y or Y/X.
 Kicker KQS follows IO point 1, kicker K90p08 follows IO 2, kicker K90p10 follows IO 3, kicker K90p36 follows IO 6.
 Kicker K90p44 follows IO 9, kicker K90p50 follows IO 10. The firing point is at IO 16.

DiagX (DX124) beamlines 1,2,3,4

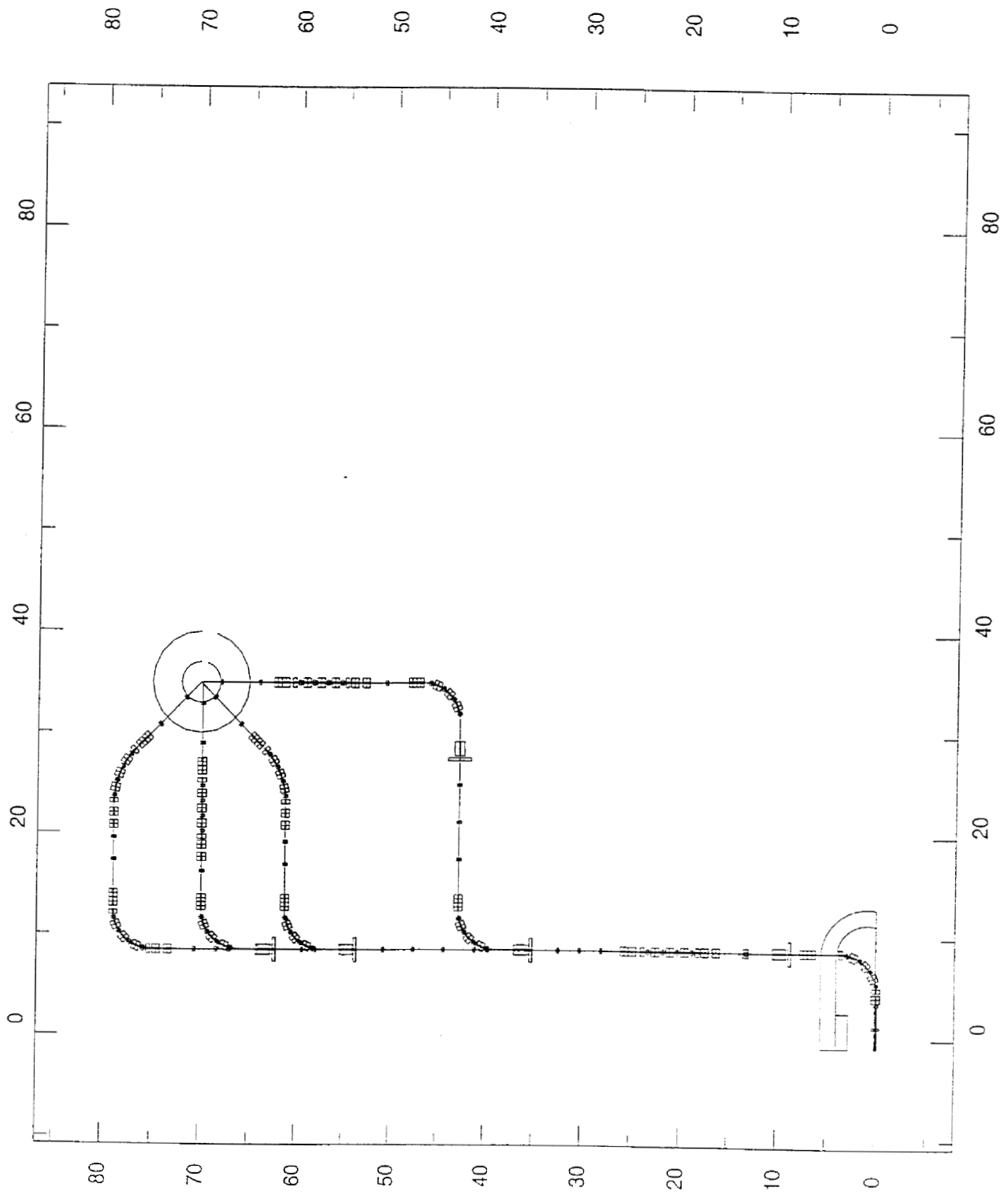


Figure 55. Four beamlines of Diagnostic X starting from the end of the accelerator and converging on the firing point.

DiagX (DX128) beamlines 5,6,7,8

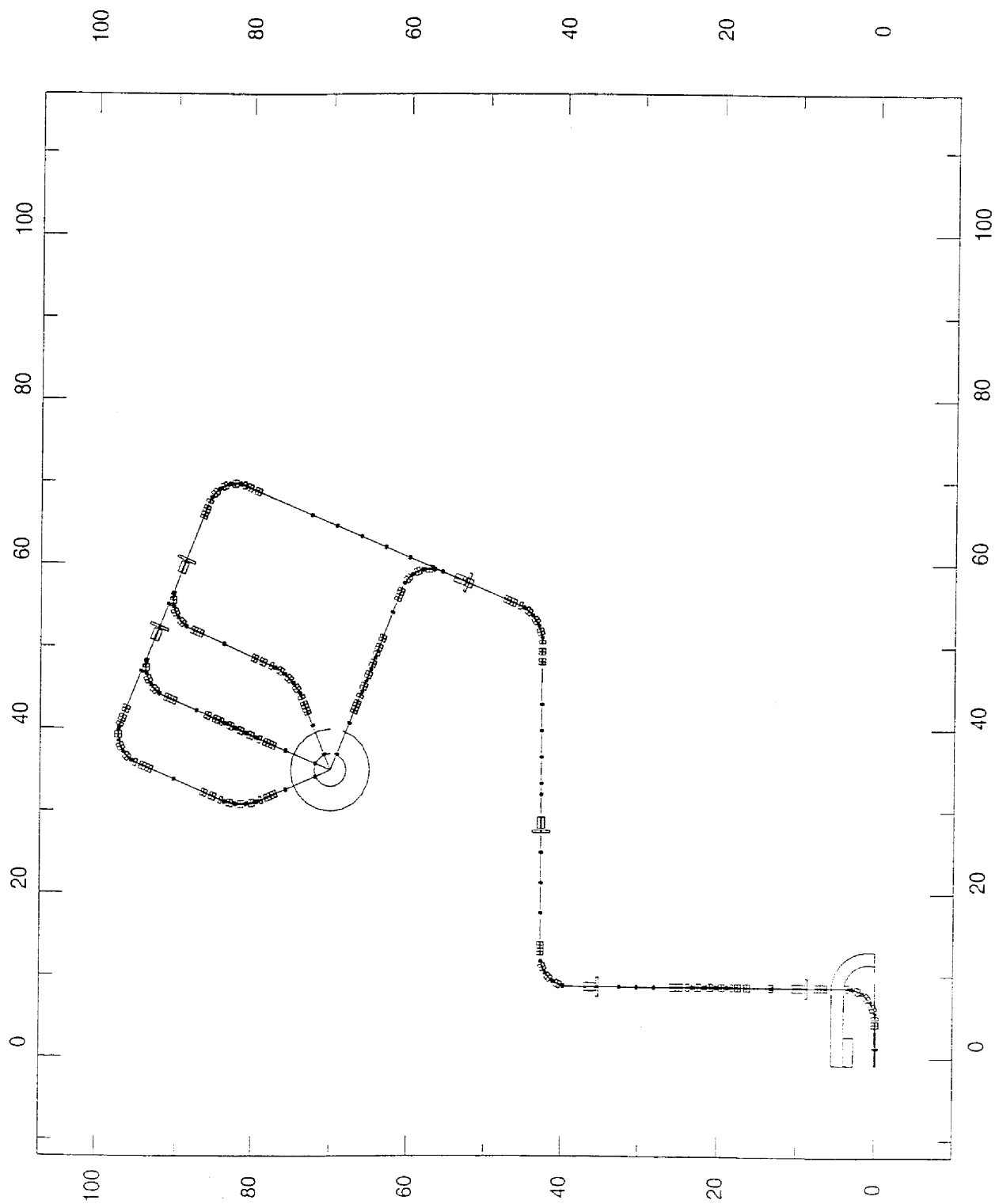


Figure 56. Four beamlines of Diagnostic X starting from the end of the accelerator and converging on the firing point.